The University of Adelaide
School of Economics

Research Paper No. 2007-05

The Tragedy of the Commons in International Fisheries: An Empirical Examination

Stephanie McWhinnie

The Tragedy of the Commons in International Fisheries: An Empirical Examination

Stephanie McWhinnie*

School of Economics, University of Adelaide
SA 5005, Australia
Telephone: +61-8-8303-5756
Facsimile: +61-8-8223-1460
stephanie.mcwhinnie@adelaide.edu.au

This Version: July 2006

*Especial thanks go to members of the Sea Around Us project for their support in accessing the catch and price data used in this paper. Continuing advice and encouragement from Brian Copeland, Gordon Munro, Rashid Sumaila, Siwan Anderson, Erwin Diewert and Jacob Wong is gratefully acknowledged, as are comments from participants at the Conference on Fisheries Economics and Management in Honour of Professor Gordon R. Munro, the Canadian Resource and Environmental Economics Study Group, the empirical and FEM lunches at the University of British Columbia, and seminar participants at Australian National University, University of Canterbury, Carleton University, Middlebury College, Ryerson University, and Wilfrid Laurier University.

The Tragedy of the Commons in International Fisheries: An Empirical Examination

Abstract

Historically, all capture fisheries have proven hard to manage; internationally shared stocks face an additional impediment to effective management. Previous fisheries studies estimate gains from cooperation for particular species or locations, but evidence is lacking on the wider effect that international sharing has in relation to other variables that affect stock status. This paper is an attempt to shed a broader light on the effect of sharing by identifying whether shared fish stocks are systematically more exploited. I compile exploitation status, biological and economic data into a unique two-period panel of more than two-hundred fish stocks from around the globe with which I test the theoretical implications of sharing. The empirical results from ordered category estimation suggest that shared stocks are indeed more prone to overexploitation.

Keywords: International fisheries, Tragedy of the Commons, exploitation status, ordered probit.

1 Introduction

The Tragedy of the Commons has long been recognized with respect to fisheries.[1] This problem of the common pool is pervasive amongst both international and domestic fisheries and managers are trying to cope, with limited success. The United Nations Convention on the Law of the Sea (United Nations (U.N.) 1982) was intended to alleviate the pressure on the international commons by extending from a usual three to a 200 nautical mile exclusive economic zone (EEZ) around a nation. Unfortunately, the Food and Agriculture Organization has reported that the percentage of stocks exploited beyond the maximum sustainable yield (MSY) has increased from 10 percent in the early 1970s to 30 percent by the late 1990s, with another 40 percent of stocks fished at MSY (FAO 2000). This evidence suggests that limiting international entry into the fishery is not satisfactory as we observe "Tragedy of the Commons" outcomes in both domestic and internationally shared fisheries.[2]

This paper analyzes international sharing by using a unique two-period panel of species from around the globe to identify whether shared fish stocks are systematically more exploited. As this is the first time global variation has been used in fisheries, I compile data on exploitation status along with economic and biological characteristics. The data comes from a variety of sources and includes newly available catch and price information on more than two-hundred fish stocks. The use of biological and economic data together allows me to test standard predictions from fishery economics theory to determine how important international sharing is in relation to other determinants of stock status.

The results of my ordered category estimation indicate that the probability of a fish stock being depleted, or over- or fully-utilised rises as the number of countries that share the stock rises, while the probability of being moderately or under-utilised falls. This negative effect of sharing is apparent both when stocks are harvested from large or small portions of nations' waters suggesting that access is all that is required to have an affect on stock status.

[1] Gordon (1954) was the first to analyse fisheries common property, and was popularised in a different context by Hardin (1968).

[2] The FAO uses the term "shared" generically to refer to transboundary, straddling and highly migratory stocks. Transboundary stocks are shared by two or more nations' EEZs and straddling and highly migratory stocks cross into international waters.

The theory of shared fisheries is considerable and various. It studies optimal management strategies (Munro 1979), the noncooperative effects on harvests and stock levels (Clark 1980, Levhari and Mirman 1980), mechanisms to attain cooperation for specific fisheries (Lindroos 2004), and the interaction between coastal states and distant water fishing nations (McKelvey, Sandal, and Steinshamn 2002). While the focus, techniques and applications of these papers may differ, the consensus is that a prisoner's dilemma outcome may result due to both static and dynamic incentives to overharvest even when the countries involved have good management otherwise. This paper explicitly tests this hypothesis across species and countries.

To date, the empirical fisheries literature has considered the potential gains of cooperation rather than testing the degree to which sharing exacerbates the problem of the common pool. Authors such as Kennedy (1999), Arnason, Magnusson, and Agnarsson (2000) and Armstrong and Sumaila (2000, 2001) use computational case studies to examine the specific gains from cooperation for particular stocks. While these papers are important in encouraging specific countries to cooperate they do not address the overarching question of how important sharing is in relation to other variables that affect stock status. Understanding the relative contributions of international sharing, domestic management, and economic and biologic characteristics will facilitate appropriate policy advice for fisheries management, particularly amongst countries that must choose where to focus their management resources and in regions where shared stocks are the rule rather than the exception.

Empirical analysis of international sharing has been carried out within other contexts. The success of international pollution reduction agreements has been found to depend on the ability to reduce international externalities (Murdoch and Sandler 1997a, 1997b) and studies have shown that international and interstate river pollution and toxic releases from border counties are higher than domestic pollution (Sigman 2002a, 2002b, Helland and Whitford 2003). In this paper, I am able to investigate whether the externalities found in the international pollution studies are consistent with the overuse of internationally shared fisheries.

Section 2 outlines the theoretical predictions from the Clark-Munro dynamic, single species fisheries model that give the framework for the empirical analysis. The distinctive dataset with which these predictions are tested is detailed in Section 3.

The empirical analysis and results of ordered category estimation are given in Section 4. Finally, the conclusion that international sharing is indeed a driving force in determining stock status is discussed in Section 5.

2 Theoretical Foundations

Before moving to the empirical analysis I present the theoretical foundations needed to determine the necessary control variables and provide predictions for the effects of said controls. A model that analyzes the interaction of multiple players is the dynamic case of a single species fisheries model as developed by Clark and Munro (1975). This gives a Cournot-Nash solution with a modified golden rule to define the equilibrium stock level. This simple Markov perfect equilibrium can be used to find implications for the variables important in determining fisheries status that are consistent with other theoretical work in fisheries. Of particular importance here, it is easy to interpret the number of players as the number of countries that own the fish stock in question.

The competitive problem for n symmetric players is to choose individual effort levels (L_{it}) to maximise their own sequence of profits taking others' effort levels (L_{jt}, $j \neq i$) and the natural growth of the fish stock as given.

$$\max_{L_{it}} \int_0^\infty e^{-\delta t} \left[pqL_{it}x_t - cL_{it}\right] dt \tag{2.1}$$

$$\text{s.t.} \quad \dot{x}_t = rx_t\left(1 - \frac{x_t}{K}\right) - qL_{it}x_t - \sum_{j\neq i} qL_{jt}x_t \tag{2.2}$$

Where profit depends on the price (p), technical capability (q), effort level (L_{it}), stock size (x_t), and average cost of effort (c). The fish stock grows dependent on the logistic natural growth function, with an intrinsic growth rate (r), natural maximum stock size (K), and stock size (x_t), less the amount of harvesting done by all players.

Taking first-order conditions of the associated Hamiltonian, Equation 2.3, the steady-state solution with identical agents is defined by the modified golden rule of Equation 2.4. The incentive to overharvest today, or underinvest in the fish stock for tomorrow, is due to the possibility that other countries may harvest the invested fish in the meantime.

$$H = e^{-\delta t}\left[pqL_{it}x_t - cL_{it}\right] + \lambda_t\left[rx_t\left(1 - \frac{x_t}{K}\right) - qL_{it}x_t - \sum_{j\neq i} qL_{jt}x_t\right] \tag{2.3}$$

$$\delta = r\left(1 - \frac{2\tilde{x}}{K}\right) - \frac{r}{n}\left(1 - \frac{\tilde{x}}{K}\right)\left[(n-1) - \frac{c}{pq\tilde{x} - c}\right] \tag{2.4}$$

From this equilibrium condition, it is easy to identify the effects of each variable by considering the comparative statics. The total derivative of Equation 2.4 is:

$$\begin{aligned}\left[(n+1)\tilde{\pi}^2 + \hat{\pi}c\right]\frac{d\tilde{x}}{\tilde{x}} &= -(\hat{\pi} - \tilde{\pi})\tilde{\pi}\frac{dn}{n} + \frac{\delta nK\tilde{\pi}^2}{r\tilde{x}}\frac{d\delta}{\delta} + \tilde{\pi}\left[\hat{\pi} - (n+1)\tilde{\pi}\right]\frac{dr}{r} \\ &+ \tilde{\pi}\left[(n+1)\tilde{\pi} + c\right]\frac{dK}{K} - (\hat{\pi} - \tilde{\pi})c\left[\frac{dq}{q} + \frac{dp}{p} - \frac{dc}{c}\right]\end{aligned} \tag{2.5}$$

where $\tilde{\pi} = pq\tilde{x} - c$ and $\hat{\pi} = pqK - c$ are the profit per unit effort when stock is at equilibrium harvest and carrying capacity, respectively.

An increase in the number of players (n), the price (p), the catchability coefficient (q), and the discount rate (δ) reduce the equilibrium stock level whereas higher carrying capacity (K) and cost (c) increase it. The intrinsic rate of growth of the stock (r) has a positive effect on the stock level if $\hat{\pi} > (n+1)\tilde{\pi}$, which is true for the relevant range of $\tilde{x}$.[3] These results are intuitively appealing, more competition and factors that increase profitability increase the pressure on the stock, while a higher natural preponderance of the stock and an increased ability to rejuvenate improve stock status.

In the data used for the empirical analysis, exploitation status of fish stocks is defined relative to the stock that gives the biological maximum sustainable yield (MSY). This stock is where the natural growth rate is maximised. From the first term in Equation 2.2 the maximum sustainable yield stock is derived as $x_{MSY} = \frac{K}{2}$. To apply the theoretical predictions above, they must be converted to give the impact on exploitation status rather than stock level. Let exploitation (X) be defined as the relative difference from the MSY stock level:

$$X = \frac{x_{MSY} - \tilde{x}}{x_{MSY}} = 1 - \frac{2}{K}\tilde{x} \tag{2.6}$$

[3] For the *bionomic* stock level, $x_{n\to\infty} = \frac{c}{pq}$, the right-hand-side is zero, so the condition is always true. For the static level of $\tilde{x}$ the condition holds with equality. From Equation 2.5 we can see that $\frac{\partial x}{\partial \delta} < 0$ thus any dynamic level of $\tilde{x}$ will be less than the static level and hence the condition will hold for any relevant $\tilde{x}$.

All the comparative statics from above, except one, are then just multiplied by $-\frac{2}{K}$, reversing their signs. The intuition remains the same, factors that harm stock level increase the degree of exploitation and vice versa. For carrying capacity (K), however, the conversion is not so simple.

$$\frac{\partial X}{\partial K} = -\frac{2}{K}\frac{\partial \tilde{x}}{\partial K} + \frac{2\tilde{x}}{K^2} = \frac{2\tilde{x}c(\hat{\pi} - \tilde{\pi})}{K^2\left[(n+1)\tilde{\pi}^2 + \hat{\pi}c\right]} \geq 0 \tag{2.7}$$

This means that a higher carrying capacity is more likely to increase the degree of exploitation relative to the biological maximum.[4]

By choosing to interpret the number of players given by the theory as the number of countries, the implicit assumption is that the countries are choosing the overall catch optimally and are perfectly able to manage their domestic fleets to only take this catch level. Of course, reality is quite different. The empirical strategy will account for this by including a measure of management ability. If a nation sticks to an optimally chosen catch, no matter with what efficiency it is distributed amongst the domestic fleet, then the theory will represent reality. If a nation is unable to enforce optimal effort it will manifest similarly to an increase in the number of players. Another twist on international sharing is harvesting in the high seas. The high seas are essentially "unowned" and open to all nations. A variable for being caught in the high seas is included in the analysis.

This theory provides the following reduced form structure for the empirical tests:

$$X = f(n, M, HS, K, r, p, q, c, \delta) \tag{2.8}$$

where X is exploitation of the fish stock, n is how many countries' waters the stock is fished in, M is the domestic management ability within those countries, HS is whether the stock is caught in the high seas or not, and the remaining variables are as defined earlier this section.

[4]The economic maximum is a preferable baseline that future work would like to consider but the currently available data only allows comparison to the biological maximum. The static theoretical predictions about the signs on the effect of explanatory variables remain the same using the economic maximum as a baseline.

3 The Data

The data for this paper has been drawn together from a variety of sources and has been collated to be useful in an economic rather than biological analysis. The dependent variable, exploitation of the fish stock (X), comes from the Food and Agriculture Organization's "Review of the state of world fishery resources: marine fisheries" (1997) and "Review of the state of world marine fishery resources" (2005). These FAO reports use data through to 1994 and 2002 respectively to assign each fish stock in each of seventeen regions,[5] as shown in Figure **??**, one of the following categories:

- U = Underexploited, undeveloped or new fishery. Believed to have a significant potential for expansion in total production;
- M = Moderately exploited, exploited with a low level of fishing effort. Believed to have some limited potential for expansion in total production;
- F = Fully exploited. The fishery is operating at or close to an optimal yield level, with no expected room for further expansion;
- O = Overexploited. The fishery is being exploited at above a level which is believed to be sustainable in the long term, with no potential room for further expansion and a higher risk of stock depletion/collapse;
- D = Depleted. Catches are well below historical levels, irrespective of the amount of fishing effort exerted;
- R = Recovering. Catches are increasing after a collapse from a previous high;
- Blank or ? = Not known or uncertain. Not much information is available to make a judgement.

Thus, an observation is the exploitation level of a stock in an FAO area in a time period. It should be noted that some species will be observed in more than one area and may have different levels of exploitation in each. After removing molluscs and crustaceans for lack of physical data, recovering as there is no natural ordering, and

[5] I use no observations from Areas 18 or 88.

blank or ? for obvious reasons, the total number of usable observations is 373. Of these 373: 165 are categorised in both periods; 23 are only categorised in 1994; and 20 are only categorised in 2002, giving 208 species-FAO area combinations, which together account for almost 40% of the volume and 50% of the value of annual marine fisheries globally. Table 1 shows the proportions in each of the exploitation categories and Figure 1 plots the frequency of exploitation status by groups of FAO areas.[6,7]

Table 1: Number and Percentage of Exploitation Status Data

	Depleted	Over	Fully	Moderate	Under	All
Exploitation	15	39	78	48	8	188
Status - 1994	8%	21%	41%	26%	4%	
Exploitation	12	46	78	45	4	185
Status - 2002	6%	25%	42%	24%	2%	

From the theory of Section 2 we can see that data on the number of countries, management, economic and physical characteristics are required. A discussion of each follows and summary statistics are presented in Table 2. The number of players (n) variable was developed from catch data from the Sea Around Us project database (2005). This data has incredible detail with catch of a fish species in a FAO area broken down across the globe into half degree by half degree cells (approximately 55km by 55km at the equator) by the nation that caught it. This data can then be aggregated to EEZ and FAO area.[8] From this data, n was calculated as the number of EEZs in a given FAO area that a species was caught in. Therefore, one species in an area may have different status and number of countries than another species in the same area, or be different from the same species in a different area. The choice to analyze sharing in this way is to capture the idea of access. As is evident from the "fish wars", access is all that is required to disrupt fish stocks; it is not necessarily the geographic share that matters.[9,10] The number of countries ranges from one to 28, with almost half being fished in five or less country's waters and one quarter fished

[6]Each North, Central and South of the Atlantic and Pacific Oceans and the Indian Ocean are further divided into West and East in the actual FAO areas used.

[7]A list of species included is given in the appendix.

[8]For the Mediterranean 'hypothetical' EEZs are used to delimit the relevant marine areas.

[9]For example on the Grand Banks of Newfoundland (Bjørndal and Munro 2003) and in the Herring loophole in the Norwegian Sea (Arnason, Magnusson, and Agnarsson 2000).

[10]I do, however, consider some alternate definitions dependent on geographic size that are discussed in Section 4.

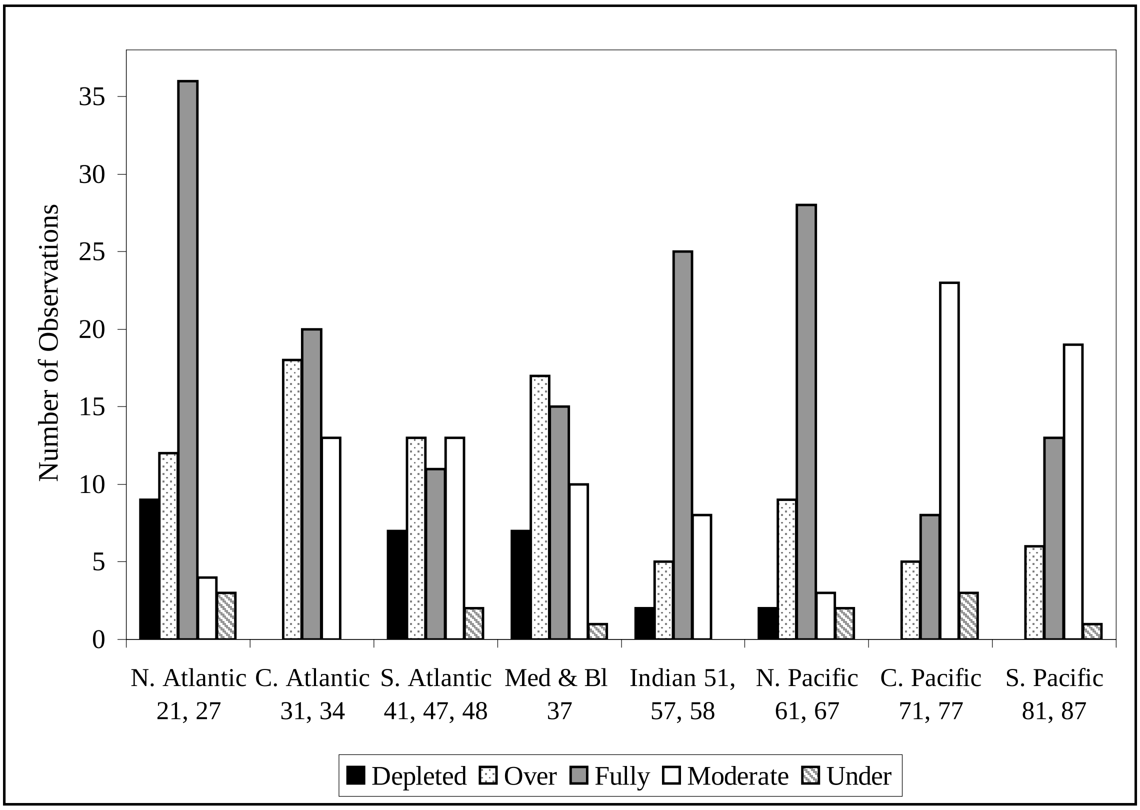

Figure 1: Frequency of Exploitation Status by Ocean Area

in sixteen or more. A dummy variable was created if the fish was harvested in the high seas to capture the effects of "unowned" areas. For clarity of how the number of countries is counted, consider the following example. Pink salmon is observed in both the NW and NE Pacific. In the NW Pacific, it is harvested in Japanese, North and South Korean, Russian, and American waters plus the high seas so it is classified as being shared by five countries and the high seas dummy equals one. In the NE Pacific, pink salmon is harvested in Canadian, Russian and American waters but not the high seas so it is classified a being shared by three countries and the high seas dummy equals zero. In contrast, Pacific halibut in the NE Pacific is harvested in Canadian, Russian and American waters and the high seas so is classified as being shared by three countries and the high seas dummy equals one.

Counting the number of countries this way may give rise to a potential endogeneity problem that as stocks get worse countries no longer find it so profitable to harvest them. However, there are two reasons to allay any concern. Firstly, countries

Table 2: Means of Explanatory Variables by Exploitation Status and Year

	Depleted		Over		Fully		Moderate		Under		All
	1994	2002	1994	2002	1994	2002	1994	2002	1994	2002	
Observations	15	12	39	46	78	78	48	45	8	4	373
Number of Countries	7.60 (7.95)	9.42 (8.24)	12.03 (7.77)	11.80 (8.72)	8.50 (7.76)	8.15 (7.08)	11.56 (8.73)	11.18 (8.95)	2.88 (1.46)	3.00 (.00)	9.73 (8.13)
Avg Real Interest Rate	8.20 (9.57)	6.54 (5.24)	7.26 (9.59)	5.53 (6.40)	8.64 (10.9)	5.16 (7.09)	8.29 (7.39)	6.35 (4.78)	12.8 (11.9)	10.8 (14.4)	7.09 (8.40)
Dbl.Time>14yr	0.07	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01
(Sub)Tropical	0.13	0.17	0.69	0.65	0.62	0.59	0.79	0.89	0.63	0.50	0.64
AvgAgVA/wkr ($10 000 US)	1.70 (.87)	2.12 (1.35)	1.04 (.66)	1.40 (.98)	1.35 (.91)	1.90 (1.47)	0.95 (.59)	1.25 (.80)	1.53 (1.10)	2.66 (1.48)	1.43 (1.07)
AvgGDP/cap ($10 000 US)	1.53 (.58)	1.71 (.80)	1.07 (.51)	1.24 (.61)	1.29 (.69)	1.56 (.88)	0.99 (.42)	1.15 (.51)	1.46 (.76)	2.02 (.78)	1.30 (.69)
Price ($000 US/tonne)	2.82 (3.80)	2.93 (3.75)	3.63 (3.68)	2.77 (3.52)	2.08 (2.18)	1.36 (1.35)	1.28 (1.32)	1.88 (3.16)	0.43 (.27)	0.62 (.56)	2.06 (2.69)
High Seas	0.47	0.58	0.33	0.41	0.55	0.59	0.54	0.47	0.63	0.75	0.51
Avg Risk Rating	73.6 (7.99)	75.1 (8.35)	68.7 (7.79)	71.9 (5.69)	71.3 (8.99)	73.4 (8.04)	69.9 (8.36)	72.1 (5.06)	74.3 (8.20)	76.5 (5.45)	71.8 (7.81)

Observations 373. 188 for 1994, 185 for 2002, 165 in both.
Standard deviations in parentheses for continuous variables.

are counted if the catch of that species from their waters is positive so if the catch rises or falls with changes in exploitation status but remains positive it does not matter. Secondly, any affect of this type will work against finding a negative effect of the number of countries, that is, countries exiting when stocks fall means a higher number of countries will be associated with better stocks rather than vice versa. The following management and economic characteristics are assigned by a simple average of the countries that are identified as sharing each stock, the simple average is used to again reflect the access criteria.[11]

Capturing the domestic management ability is difficult. Measures based on fisheries management specifically are most likely endogenous as "good " management is frequently only implemented in a restorative fashion after overfishing has occurred rather than in a preventative fashion. Hence, we would observe a positive relationship between "good" management and "bad" outcomes. To avoid this problem I use a more general measure of the enforcement of property rights: the PRS Group's "International Country Risk Guide" rating (accessed via the World Development

[11] I also tried weighting the economic variables by proportion of catch and found that it altered little. As I was concerned about weighting by a choice variable I report only the equal weighted results.

Indicators (2004)), which rates political, financial, and economic risk. This measure is then averaged across owner countries, where a country is defined as an owner of a species if that species was caught in that country's waters.

The economic variables contributing to exploitation are also difficult to measure and hence why case studies have been used in the past. This paper uses a new price database developed as part of the Sea Around Us project (2005). This database is a collection of fisheries prices from around the globe and across time, all in US dollars per tonne. I use the mean observed price for each species in each year; if the exact species was unavailable I used the closest species, determined by taxonomy and location. This provides me with a measure of the world price of each species, albeit imperfectly. The advantage of using one world price for each species is that avoids potential local endogeneity of price; note also that prices are relatively constant in this time period, if anything, prices have fallen while depletion has risen. Costs are measured more imperfectly by agricultural value added per worker, as an average across owner countries. This data includes fisheries value added and is used like an opportunity cost to represent wages because a consistent and comparable wage data source has proved elusive.[12] Ideally, technical capability would be country and fishery specific, in this paper I use gross domestic product (GDP) per capita to reflect richer, more capital intensive countries, once again as an average across owner countries. Annual data on per capita GDP is available from the Penn World Tables (2002); the annual agricultural value added per worker data is from the World Development Indicators (2004), as is the real annual interest rate that I use as a measure of the discount rate. Note that just one year of each explanatory variable is used; the results are almost identical for different years so I use data from 1992 and 2000 for my explanatory variables to allow for a small lag in the effect on exploitation status.

Finally, physical characteristics need to be accounted for. Data on fish stock doubling time (greater than 14 years, 4.5-14 years, 1.4-4.4 years and less than 15 months) and climate (deep-water, polar, temperate, subtropical and tropical), amongst various other biological information under separate entries for each species, is available from Fishbase (2005). These were converted into sets of dummy variables and are

[12] I do conduct a version in Section 4 using a measure of wages from the Occupational Wages from Around the World Database (2005), unfortunately, the coverage is limited so I lose more than half my sample.

used to capture the growth rate of the stock and the carrying capacity (or productivity) of the environment.

4 Empirical Analysis and Results

As the dependent variable is categorically ordered, an ordered probit analysis is called for. This takes the explanatory variables and estimates the probability of being in each exploitation category (depleted, overexploited, fully exploited, moderately exploited and underexploited). The following regression is estimated for fish stock i in FAO area l at time period t.[13]

$$\begin{aligned} Pr(Exploitation_{ilt}) \;=\; & f(Number\ of\ Countries_{ilt},\ Price_{it},\ Climate_i, \\ & Doubling\ Time_i,\ Average\ Real\ Interest\ Rate_{ilt}, \\ & Average\ GDP/Capita_{ilt},\ Average\ Agriculture \\ & Value\ Added/Worker_{ilt},\ Average\ Risk\ Rating_{ilt}, \\ & High\ Seas\ Dummy_{ilt},\ Year\ Dummy) \end{aligned}$$

With the data as an unbalanced two-period panel I also include a dummy variable for the later period and use the GLLAMM programme (Skrondal and Rabe-Hesketh 2003) for Stata 8 (2003) to estimate a random-effects panel ordered probit.

The coefficients of the ordered probit model only indicate whether the variables generally improve the exploitation status or not, so we should generally examine the marginal effects. Marginal effects tell us how much the probability of being in each exploitation category changes for a one unit change in a particular variable, or for a discrete jump in a dummy variable. However, after presenting the marginal effects for the base specification I shall only present coefficients of remaining specifications to save space. The coefficients and marginal effects for each exploitation category for the initial regression are reported in Table 3. The number of countries is statistically significant at the 5% level and works in the anticipated direction; the more countries a fish stock is shared between, the more likely it is to be overexploited or depleted. The positive coefficient on the squared term reduces this impact but is not statistically significant. This result can be more clearly seen in Figure 2 where the

[13] All standard errors are clustered at the species-FAO area level.

Table 3: Base Ordered Probit: Coefficients and Marginal Effects

Dependant Var. Exploitation	Base Version	dD dx	dO dx	dF dx	dM dx	dU dx
Number of Countries	-.1282 ** (.058)	.0039	.0076	-.0008	-.0094	-.0014
Number Sq.	.0032 (.002)					
High Seas	.6012 ** (.279)	-.0293	-.0667	-.0070	.0855	.0175
(Sub)Tropical	1.871 *** (.667)	-.1908	-.1414	.1326	.1834	.0162
Dbl.Time>14yr	-2.113 *** (.619)	.2321	.1423	-.1628	-.1953	-.0164
Price ($000 US/tonne)	-.1479 *** (.050)	.0087	.0168	-.0017	-.0207	-.0031
Avg Real Interest Rate	.0064 (.010)	-.0004	-.0007	.0001	.0009	.0001
Avg GDP/cap ($10 000 US)	-1.472 * (.819)	.0876	.1576	-.0160	-.1960	-.0332
Avg Ag VA/wkr ($10 000 US)	.6837 (.440)	-.0403	-.0766	.0077	.0946	.0145
Avg Risk Rating	.0324 (.025)	-.0019	-.0037	.0004	.0045	.0007
Year 2002	-.4281 ** (.191)	.0221	.0482	.0022	-.0611	-.0114

Obs: 373. Log likelihood -420.868
Significance levels: *10% **5% ***1%. Clustered standard errors of coefficients in parentheses.
The marginal effects for Number of Countries includes the effect via the squared term.

predicted probability of being in each exploitation category is given, evaluating all other variables at their means and only allowing the number of countries fished in to change.

These predicted proportions mean that if a fish stock is shared between two countries it is 7% more likely to be overfished and 14% more likely to be depleted than a stock fished by one country. If the stock is shared by five countries it is 28% more likely to be overfished and 60% more likely to be depleted. When the stock is shared by ten countries it is 56% more likely to be overfished and 136% more likely to be depleted than a stock fished by just one country.

Moving to the biological variables, a more productive (subtropical or tropical) climate works consistently with the raw stock effect, a better climate increases the stock. However, from the form of Equation 2.7, a better climate should, somewhat counterintuitively, increase exploitation relative to the biological maximum level,

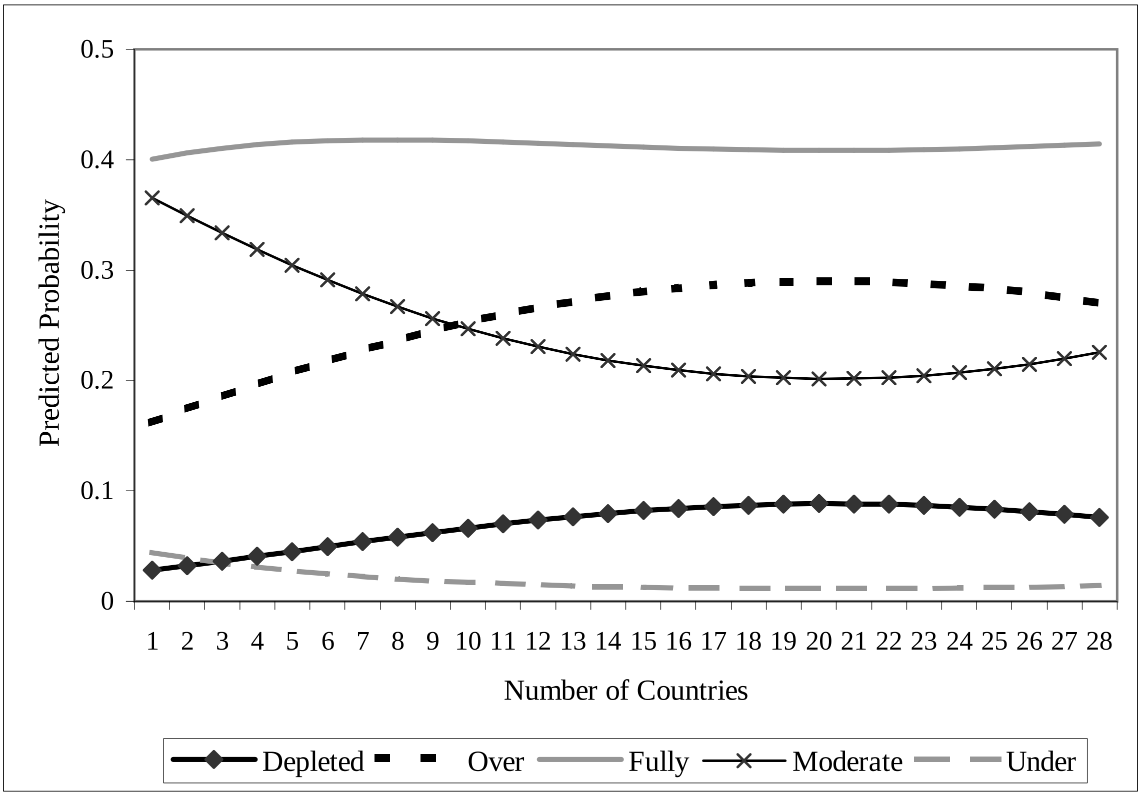

Figure 2: Predicted Probabilities of Exploitation Status Categories as Number of Countries Rises, Using Base Ordered Probit Coefficients

which does not hold up in the data. Having a very slow doubling time (greater than 14 years) has statistically significant negative impact.[14] A higher price works in the anticipated direction by increasing the chance of a stock being overexploited or depleted; higher GDP/capita works in the same direction. Neither Agricultural Value Added/worker nor Risk have statistically significant impacts but the signs are consistent with the theory. A curious result is the positive effect that being harvested in the high seas has on exploitation status. It is puzzling in that the high seas are the last remaining true commons and should therefore be "unowned" and more likely to be exploited. However, the distance from shore combined with the high seas stocks being generally more migratory may be providing some degree of natural protection.

[14]For expositional ease I report results for groups of climate and doubling time variables throughout. The groups were chosen as results from the complete specification indicate that subtropical and tropical climates have very similar coefficients, as do all the doubling time categories other than very slow.

Table 4: Coefficients of Alternative Specifications

Dependant Var. Exploitation	Base Version	with Std Deviations	with Polity Alternative	with Wages (156 obs)	with Real Disc. Rate (358 obs)
Number of Countries	-.1282 ** (.058)	-.1365 * (.078)	-.1240 ** (.060)	-.0887 (.081)	-.1662 *** (.063)
Number Sq.	.0032 (.002)	.0033 (.003)	.0031 (.003)	.0032 (.003)	.0046 * (.003)
High Seas	.6012 ** (.279)	.8045 *** (.303)	.5998 ** (.299)	.0211 (.288)	.6103 ** (.281)
(Sub)Tropical	1.871 *** (.667)	1.197 * (.668)	1.925 *** (.675)	.9596 *** (.349)	1.559 *** (.598)
Dbl.Time>14yr	-2.113 *** (.619)	-3.031 *** (.687)	-1.954 *** (.635)	-.1976 (.400)	-2.317 *** (.732)
Price ($000 US/tonne)	-.1479 *** (.050)	-.1142 ** (.050)	-.1501 *** (.051)	-.1205 (.076)	-.1382 *** (.051)
Avg Real Interest Rate	.0064 (.010)	.0183 (.018)	.0050 (.010)	.0215 (.039)	
Avg GDP/cap ($10 000 US)	-1.472 * (.819)	-1.916 * (1.08)	-.9987 (.698)	-1.096 * (.565)	-1.550 * (.822)
Avg Ag VA/wkr ($10 000 US)	.6837 (.440)	.9057 * (.513)	.5225 (.424)		.7029 (.433)
Avg Risk Rating	.0324 (.025)	-.0230 (.031)		.0860 ** (.039)	.0359 (.025)
Year 2002	-.4281 ** (.191)	-.0246 ** (.010)	-.4107 ** (.190)	-.0606 (.252)	-.4540 ** (.185)
SD Money Market Rate		1.107 (.855)			
SD GDP/cap ($10 000 US)		.0458 (.566)			
SD Ag VA/wkr ($10 000 US)		-.0464 (.033)			
SD Risk Rating		-.7486 *** (.220)			
Avg Polity Rating			.0300 (.041)		
Wages ($10 000 US)				-.0009 (.001)	
Avg Real Discount Rate					.0004 (.001)
Log likelihood:	-420.868	-399.098	-421.281	-171.265	-399.165

Obs: 373. Significance levels: *10% **5% ***1%. Clustered standard errors in parentheses.

The next step in the examination of international sharing is to examine a variety of different specifications of the explanatory variables. Table 4 shows the coefficients for these specifications with the base version in the first column. The second column shows the results of including the standard deviations of the owner-countries' variables.[15] These were included as a way to allow for the empirically observed heterogeneity of countries that is not present in the theoretical model. Including the standard deviations along with the means reinforces the results of the basic model and only the standard deviation of the risk rating has a statistically significant impact suggesting the heterogeneity is not such an important factor. This is perhaps not surprising as the countries are already being grouped by FAO area where neighbours have more similar characteristics than is observed on global scale.

The third column of Table 4 gives the results of one of three alternate measures of management ability, the average Polity rating. The Polity rating comes from the "Integrated Network for Societal Conflict Research Program" and is a measure of political regime characteristics including democratic process, stability, executive power and so forth. Like the Risk rating, it does not have a statistically significant impact but its sign follows the theory. Two other measures were also used with similar results: the Heritage Foundation's "Index of Economic Freedom"; and the index of property rights, one of the ten components of the Economic Freedom index.

Finding a consistent measure of wages proved almost impossible but the Occupational Wages from Around the World Database (2005) gives average monthly wage rates for male workers in US dollars. Unfortunately, the coverage is limited so only 156 of my 373 observations are included in this version, presented in the fourth column. Consequently, the power of the regression falls but the coefficients are generally similar and wages are still not significant. Finally, instead of using the real interest rate I use the real discount rate of the central bank. As can be seen in column five, the results are robust this alternate measure.

Of further interest is the effect of the degree of sharing. Until now, a country has been counted as an owner of the stock if any of the species is harvested in that country's waters. Table 5 presents a variety of different specifications that restrict ownership in a variety of ways. The second column only counts countries that harvest more than one percent of the catch of that species in that FAO area. While the coefficient on the Number of Countries increases in magnitude it reduces in power. This is not surprising as a restriction based on percent catch will necessarily be more binding for stocks with many countries thus the maximum number of countries is

[15]Recall that the coefficients just indicate the direction of the effect rather than specific effects on each category. A negative sign means more of that variable worsens the status of the stocks.

Table 5: Coefficients of Examining Geographic Size

Dependant Var. *Exploitation*	Base Version	≥ 1% of Catch	≥ 1% of Own EEZ Cells	≥ 1% of All FAO Cells	≥ 1 tonne of Catch
Number of Countries	-.1282 ** (.058)	-.2150 (.137)	-.1293 * (.069)	-.2314 ** (.096)	-.1281 ** (.063)
Number Sq.	.0032 (.002)	.0125 (.010)	.0032 (.003)	.0078 (.006)	.0033 (.003)
High Seas	.6012 ** (.279)	.3440 (.332)	.5961 * (.362)	1.068 ** (.530)	.7236 ** (.298)
(Sub)Tropical	1.871 *** (.667)	1.716 *** (.654)	1.781 *** (.672)	1.655 *** (.463)	1.741 *** (.660)
Dbl.Time>14yr	-2.113 *** (.619)	-2.117 *** (.674)	-2.284 *** (.709)	-2.798 *** (.864)	-2.178 *** (.665)
Price ($000 US/tonne)	-.1479 *** (.050)	-.1443 *** (.048)	-.1485 *** (.051)	-.1644 *** (.053)	-.1446 *** (.052)
Avg Real Interest Rate	.0064 (.010)	.0074 (.012)	.0081 (.011)	.0078 (.012)	.0058 (.011)
Avg GDP/cap ($10 000 US)	-1.472 * (.819)	-1.043 (.821)	-1.311 (.820)	-1.189 (.801)	-1.546 * (.837)
Avg Ag VA/wkr ($10 000 US)	.6837 (.440)	.4727 (.460)	.6361 (.451)	.6031 (.450)	.7120 (.441)
Avg Risk Rating	.0324 (.025)	.0384 (.024)	.0337 (.025)	.0328 (.025)	.0334 (.024)
Year 2002	-.4281 ** (.191)	-.4346 ** (.194)	-.4316 ** (.186)	-.4488 ** (.190)	-.4110 ** (.187)
Log likelihood:	-420.868	-423.415	-421.496	-418.211	-419.926

Obs: 373. Significance levels: *10% **5% ***1%. Clustered standard errors in parentheses.

now only seventeen compared to the previous high of 28. The remaining columns use geographic measures to restrict the counts to reduce this problem.

The third column of Table 5 only counts countries for which the stock is harvested in more than one percent of that country's waters. The results are almost identical to the base version and continue to be very similar as the percentage is increased. The fourth column continues along this line and only counts countries for which the stock is harvested in more than one percent of all the cells in the FAO area. All results in this specification strengthen the results of the base version. These two sets of results suggest that access is what matters supporting my original specification. Lastly, column five only counts countries that harvest more than one tonne of that stock in that area; this version essentially eliminates any catch data anomalies and the base results are robust to this.

The penultimate table examines the effect of location and time in more detail.

Table 6: Coefficients of Examining Place and Time

Dependant Var. *Exploitation*	Base Version	with Oceans	with Time Interactions	Interaction
Number of Countries	-.1282 ** (.058)	-.1375 ** (.058)	-.1205 (.075)	-.0123 (.085)
Number Sq.	.0032 (.002)	.0037 (.002)	.0035 (.003)	-.0004 (.003)
High Seas	.6012 ** (.279)	.7050 ** (.285)	.8969 *** (.337)	-.5298 * (.319)
(Sub)Tropical	1.871 *** (.667)	1.583 *** (.584)	1.662 ** (.718)	.3976 (.360)
Dbl.Time>14yr	-2.113 *** (.619)	-2.373 *** (.748)	-1.813 * (.958)	-.8554 (.802)
Price ($000 US/tonne)	-.1479 *** (.050)	-.1519 *** (.045)	-.1860 *** (.048)	.0532 (.056)
Avg Real Interest Rate	.0064 (.010)	.0170 (.016)	.0056 (.011)	-.0052 (.016)
Avg GDP/cap ($10 000 US)	-1.472 * (.819)	-2.233 * (1.140)	-.7720 (1.357)	-.5769 (1.732)
Avg Ag VA/wkr ($10 000 US)	.6837 (.440)	1.047 (.675)	-.2122 (.953)	.8477 (1.109)
Avg Risk Rating	.0324 (.025)	.0371 (.029)	.0541 ** (.026)	-.0097 (.015)
Year 2002	-.4281 ** (.191)			
North Atlantic*2002		-.6532 (.582)		
Central Atlantic*2002		-.8048 ** (.322)		
South Atlantic*2002		-.7624 ** (.315)		
Indian*2002		-.4187 (.327)		
North Pacific*2002		.1981 (.395)		
Central Pacific*2002		.7139 ** (.361)		
South Pacific*2002		-.3640 (.468)		
Log likelihood:	-420.868	-413.306	-416.605	

Obs: 373. Significance levels: *10% **5% ***1%. Clustered standard errors in parentheses.

The second column of Table 6 allows different time effects for different ocean areas; the Central and South Atlantic fare worse than the 1994 average while the Central Pacific fares relatively better. Various specifications of this type were tried, including both 1994 and 2002 area specific effects and trends and including FAO area specific effects and trends, and the qualitative results were similar but the power falls. The last two columns together present a specification where all variables are included and are also interacted with a dummy for the year 2002 allowing for variable specific time effects. Once again, the qualitative results are similar even though the power falls. Generally the interaction terms are not interesting nor significant suggesting the additional impact of 2002 is not variable specific. However, the high seas interaction term is a large negative and is significant at the 10% level indicating that there has perhaps been a move to harvesting from the high seas as national waters become more depleted and/or regulated.

In addition, for econometric thoroughness, I considered three different econometric models and report the results in Table 7. I first ignored the panel structure of the data and ran an ordered probit with errors clustered at the species-FAO area level with similar qualitative results but with magnitudes of generally half the size. I next returned to the panel formation but ignored the purely categorical interpretation of the exploitation status categories and treated exploitation as a linear variable (that is, being depleted is five times worse than being underexploited). The last two columns of Table 7 show the random and fixed effects versions of this linear panel regression. Once more the qualitative results are similar supporting the results of the earlier econometric specification. A Hausman test rejects the hypothesis that the difference in coefficients between the random and fixed effects specifications is not systematic but did not reject the same hypothesis for different specifications of this linear version.

Finally, I also investigated a variety of other specifications, a few of which I will briefly discuss here. Using ordered logit rather than probit gave almost identical results while two bivariate versions, where Depleted and Over (and Fully) were compared to (Fully and) Moderately and Under, support the base version. Whether a stock was harvested in two, three, four, or five-plus FAO areas did not seem to help nor hinder stock status. A few countries are of interest, for their fisheries management or from curiosity, so I use a set of dummies for Australia, Canada, Iceland, New Zealand or the United States being amongst the owners but none were notable after controlling for ocean area.

Table 7: Coefficients of Alternative Econometric Models

Dependant Var. Exploitation	Base Version Random Effects Ordered Probit	Ordered Probit without Random Effects	Linear in Exploitation Fixed Effects	Linear in Exploitation Random Effects
Number of Countries	-.1282 **	-.0686 *	-.1203	-.0449
	(.058)	(.037)	(.120)	(.030)
Number Sq.	.0032	.0021 *	.0029	.0012
	(.002)	(.001)	(.003)	(.001)
High Seas	.6012 **	.3330 **	.5820	.3297 ***
	(.279)	(.152)	(.516)	(.121)
(Sub)Tropical	1.8706 ***	.7586 ***		.6383 ***
	(.667)	(.193)		(.150)
Dbl.Time>14yr	-2.1131 ***	-1.0292 *		-.9232
	(.619)	(.552)		(.598)
Price ($000 US/tonne)	-.1479 ***	-.1061 ***	.0078	-.0591 ***
	(.050)	(.032)	(.030)	(.018)
Avg Real Interest Rate	.0064	.0004	.0029	.0025
	(.010)	(.008)	(.008)	(.006)
Avg GDP/cap ($10 000 US)	-1.4722 *	-.5520	-.9915	-.5298
	(.819)	(.486)	(.657)	(.379)
Avg Ag VA/wkr ($10 000 US)	.6837	.1915	.4208	.2569
	(.440)	(.255)	(.254)	(.194)
Avg Risk Rating	.0324	.0254	-.0053	.0108
	(.025)	(.016)	(.022)	(.012)
Year 2002	-.4281 **	-.1525	-.1000	-.1604 **
	(.191)	(.093)	(.123)	(.066)
Constant			4.4233 **	2.3373 ***
			(1.770)	(.777)
Log likelihood:	-420.868	-467.455		
Overall R^2:			0.0245	0.1661
			Hausman Test $\chi^2(9) = 42.84$	

Obs: 373. Significance levels: *10% **5% ***1%. Clustered standard errors in parentheses.

5 Conclusions

This paper uses a unique dataset on a panel of species from around the globe to identify the effect of international sharing on the status of the fish stock. I find that international sharing is indeed a detrimental force in determining stock status and that stocks harvested from large or small portions of nations' waters are equally susceptible. This result is robust to a variety of specifications. Hence, it may be concluded that policy advice that ignores the role of international sharing does a disservice to the countries and fish stocks involved. Further, while direct consideration of the effects of international cooperation is not considered here, the poor performance of shared stocks compared to their solely owned counterparts does suggest that regional fisheries management organizations should be useful as forums for cooperatively managing shared fish stocks. Finally, this international tragedy of the commons in fisheries is consistent with free-riding results found in international pollution studies.

Given the time period limitations of this study, an extension of the panel of data would be desirable. A longer panel would allow a comparison of the differences in international property rights from the 1980s to 1990s and would also enable consideration of cooperative efforts at an international level, particularly anything in the flavour of regional fisheries management organizations, to better predict the outcomes of these organizations.

A Fish Species by Ocean Area

N. Atlantic

- American angler
- American plaice
- Atlantic cod
- Atlantic herring
- Atlantic horse mackerel
- Atlantic mackerel
- Atlantic menhaden
- Atlantic salmon
- Blue whiting
- Capelin
- European pilchard
- European plaice
- European sprat
- Greenland halibut
- Haddock
- Norway pout
- Saithe/Pollock
- Sandeels nei
- Silver hake
- Summer flounder
- Tusk/Cusk
- White hake
- Whiting
- Winter flounder
- Witch flounder
- Yellowtail flounder

C. Atlantic

- Albacore
- Atlantic horse mackerel
- Atlantic menhaden
- Atlantic Spanish mackerel
- Atlantic thread herring
- Bigeye grunt
- Bigeye tuna
- Bobo croaker
- Carangidae
- Chub mackerel
- Common dentex
- Common sole
- Croakers/Drums
- European hake
- European pilchard
- Flyingfishes
- Grouper
- Grunts
- Gulf menhaden
- Jack and horse mackerels
- King mackerel
- Round sardinella
- Sciaenids
- Senegalese hake
- Skipjack tuna
- Snapper
- Yellowfin tuna

Med & Black

- Albacore
- Atlantic bluefin tuna
- Atlantic bonito
- Azov sea sprat
- Bogue
- Chub mackerel
- Common dentex
- Common pandora
- Common sole
- Dusky grouper
- European anchovy
- European hake
- European pilchard
- European sprat
- Flathead grey mullet
- Flounders/Halibuts/Soles
- Gilthead seabream
- Jack and horse mackerels
- Mullets
- Picarels
- Plain bonito
- Pontic shad
- Porgies/Seabreams
- Red mullet
- Red mullet
- Sardinellas
- Swordfish
- Whiting

S. Atlantic

- Albacore
- Antarctic rockcods/Noties
- Argentine anchovy
- Argentine croaker
- Argentine hake
- Bigeye tuna
- Blackfin icefish
- Brazilian sardinella
- Cape horse mackerel
- Kingklip
- Mackerel icefish
- Panga seabream
- Patagonian grenadier
- Patagonian toothfish
- Pink cusk-eel
- Snoek
- Southern African anchovy
- Southern African pilchard
- Southern blue whiting
- Southern bluefin tuna
- Southern hake
- Striped weakfish
- Whitehead's round herring
- Whitemouth croaker

Indian

- Anchovies
- Bigeye tuna
- Bombay-duck
- Chacunda gizzard shad
- Croakers/Drums
- Indian mackerel
- Indian oil sardine
- Kawakawa
- Largehead hairtail
- Mackerel icefish
- Narrow-barred Spanish mackerel
- Patagonian toothfish
- Ponyfishes/Slipmouths
- Sardinellas
- Scads
- Sea catfishes
- Skipjack tuna
- Threadfin breams
- Toli shad
- Yellowfin tuna

N. Pacific

- Alaska pollock
- Chinook salmon
- Chub mackerel
- Chum salmon
- Coho salmon
- Japanese anchovy
- Japanese jack mackerel
- Japanese pilchard
- Largehead hairtail
- Pacific cod
- Pacific halibut
- Pacific herring
- Pacific ocean perch
- Pacific saury
- Pink salmon
- Sablefish
- Sockeye salmon
- Yellow croaker
- Yellowfin sole

C. Pacific

- Anchovies
- Bali sardinella
- California pilchard
- Californian anchovy
- Chub mackerel
- Flyingfishes
- Indian mackerels
- Kawakawa
- Largehead hairtail
- Lizardfishes
- Mullets
- Pacific anchoveta
- Pacific jack mackerel
- Pacific thread herring
- Ponyfishes/Slipmouths
- Sardinellas
- Scads
- Sea catfishes
- Skipjack tuna
- Threadfin breams
- Toli shad
- Yellowfin tuna

S. Pacific

- Barracudas
- Blue grenadier
- Blue mackerel
- Butterfishes/Pomfrets
- Chub mackerel
- Greenback horse mackerel
- Jack and horse mackerels
- Misc demersal fishes
- Mullets
- Orange roughy
- Oreo dories
- Pacific thread herring
- Patagonian grenadier
- Patagonian toothfish
- Red codling
- Silver gemfish
- Snoek
- South Pacific breams
- Southern blue whiting
- Southern hake
- White trevally

References

Armstrong, C. W., and U. R. Sumaila (2000): "Cannibalism and the Optimal Sharing of the North-East Atlantic Cod Stock: A Bioeconomic Model," *Journal of Bioeconomics*, 2, 99–115.

——— (2001): "Optimal Allocation of TAC and the Implications of Implementing an ITQ Management System for the North-East Arctic Cod," *Land Economics*, 77(3), 350–359.

Arnason, R., G. Magnusson, and S. Agnarsson (2000): "The Norwegian Spring-Spawning Herring Fishery: A Stylised Game Model," *Marine Resource Economics*, 15(4), 293–319.

Bjørndal, T., and G. R. Munro (2003): "The Management of High Seas Fisheries Resources and the Implementaion of the UN Fish Stocks Agreement of 1995," in *The International Yearbook of Environmental and Resource Economics*, ed. by T. Tietenberg, and H. Folmer. Edward Elgar, Cheltenham, UK and Northampton, MA, USA.

Clark, C. W. (1980): "Restricted Access to Common-Property Fishery Resources," in *Dynamic Optimization and Mathematical Economics*, ed. by P.-T. Liu. Plenum Press, New York.

Clark, C. W., and G. R. Munro (1975): "The Economics of Fishing and Modern Capital Theory: A Simplified Approach," *Journal of Environmental Economics and Manangement*, 2, 92–106.

FAO (1997): "Review of the State of World Fishery Resources: Marine Fisheries," FAO Fisheries Circular 920, Food and Agriculture Organisation, Marine Resources Service, Fishery Resources Division, Fisheries Department, Rome.

——— (2000): "The State of World Fisheries and Aquaculture," Food and Agriculture Organisation, Rome.

——— (2005): "Review of the State of World Marine Fishery Resources," FAO Fisheries Technical Paper 457, Food and Agriculture Organisation, Marine Resources Service, Fishery Resources Division, Fisheries Department, Rome.

Freeman, R. B., and R. H. Oostendorp (2005): "Occupational Wages from Around the World Database," World Wide Web electronic publication, www.nber.org/oww.

Froese, R., and D. Pauly (2005): "FishBase," World Wide Web electronic publication, www.fishbase.org.

Gordon, H. (1954): "The Economic Theory of a Common-Property Resource: The Fishery," *Journal of Political Economy*, 62, 124–142.

Hardin, G. (1968): "The Tragedy of the Commons," *Science*, 162, 1243–1248.

Helland, E., and A. B. Whitford (2003): "Pollution Incidence and Political Jurisdiction: Evidence From the TRI," *Journal of Environmental Economics and Management*, 46, 403424.

Heston, A., R. Summers, and B. Aten (2002): "Penn World Table Version 6.1," Center for International Comparisons at the University of Pennsylvania (CICUP).

Kennedy, J. (1999): "A Dynamic Model of Cooperative and Non-Cooperative Harvesting of Southern Bluefin Tuna with an Open Access Fringe," in *1999 World Conference on Natural Resource Modeling*. Resource Modeling Association.

Levhari, D., and L. Mirman (1980): "The Great Fish War: An Example Using a Dynamic Cournot-Nash Solution," *Bell Journal of Economics*, 11, 649–661.

Lindroos, M. (2004): "Sharing the Benefits of Cooperation in the Norwegian Spring-Spawning Herring Fishery," *International Game Theory Review*, 6(1), 35–53.

McKelvey, R. W., L. K. Sandal, and S. I. Steinshamn (2002): "Fish Wars on the High Seas: A Straddling Stock Competition Model," *International Game Theory Review*, 4, 53–69.

MUNRO, G. R. (1979): "The Optimal Management of Transboundary Renewable Resources," *The Canadian Journal of Economics*, 12(3), 355–376.

MURDOCH, J., AND T. SANDLER (1997a): "Voluntary Cutbacks and Pretreaty Behaviour: The Helsinki Protocol and Sulfur Emissions," *Public Finance Review*, 25(2), 139–162.

——— (1997b): "The Voluntary Provision of a Pure Public Good: The Case of Reduced CFC Emissions and the Montreal Protocol," *Journal of Public Economics*, 63, 331–349.

SEA AROUND US PROJECT (2005): "Sea Around Us Project Database," World Wide Web electronic publication, www.seaaroundus.org.

SIGMAN, H. (2002a): "Federalism and Transboundary Spillovers: Water Quality in US Rivers," mimeo, Rutgers University.

——— (2002b): "International Spillovers and Water Quality in Rivers: Do Countries Free Ride?," *American Economic Review*, 92, 1152–1159.

SKRONDAL, A., AND S. RABE-HESKETH (2003): "Multilevel Logistic Regression for Polytomous Data and Rankings," *Psychometrika*, 68(2), 267–287.

STATACORP (2003): *Stata Statistical Software: Release 8.* College Station, TX: Stata Corporation.

UNITED NATIONS (U.N.) (1982): "United Nations Convention on the Law of the Sea," Doc. a/conf. 62/122, United Nations.

WORLD BANK (2004): "World Development Indicators," World Bank CD-Rom.