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Not Just Fish 2

Value of Marine Ecosystems on the Atlantic and Pacific Coasts

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INTRODUCTION

This chapter demonstrates that the ecosystems supporting the marine fisheries on Canada's east and west coasts have greatly changed under exploitation by industrial fisheries. These changes, reflected in the decline in the abundance of key species and the composition of the fisheries' landings, imply changes in the support provided by the ecosystems in which the fisheries are embedded. This further implies that ecosystem changes contribute sufficiently to the dynamics of fisheries to require their being considered explicitly in assessment and predictions, along with the within-species changes (e.g., of population structure or abundance) that have so far been the almost exclusive object of attention for fisheries scientists and managers.

Some longer-term economic and ethical implications of the trends presented here are discussed, following a presentation of the ecosystems and of an index of fisheries impacts on them, from the beginning of the century to the present, for both the eastern and western coasts of Canada.

MATERIAL AND METHODS

There are various ways ecosystems may be represented; one of these is in the form of networks representing the fluxes of food consumed by their various organisms. The ecosystem models in Figures 1 and 2 were constructed by A. Bundy, G. Lilly, and P. Sheldon (forthcom-

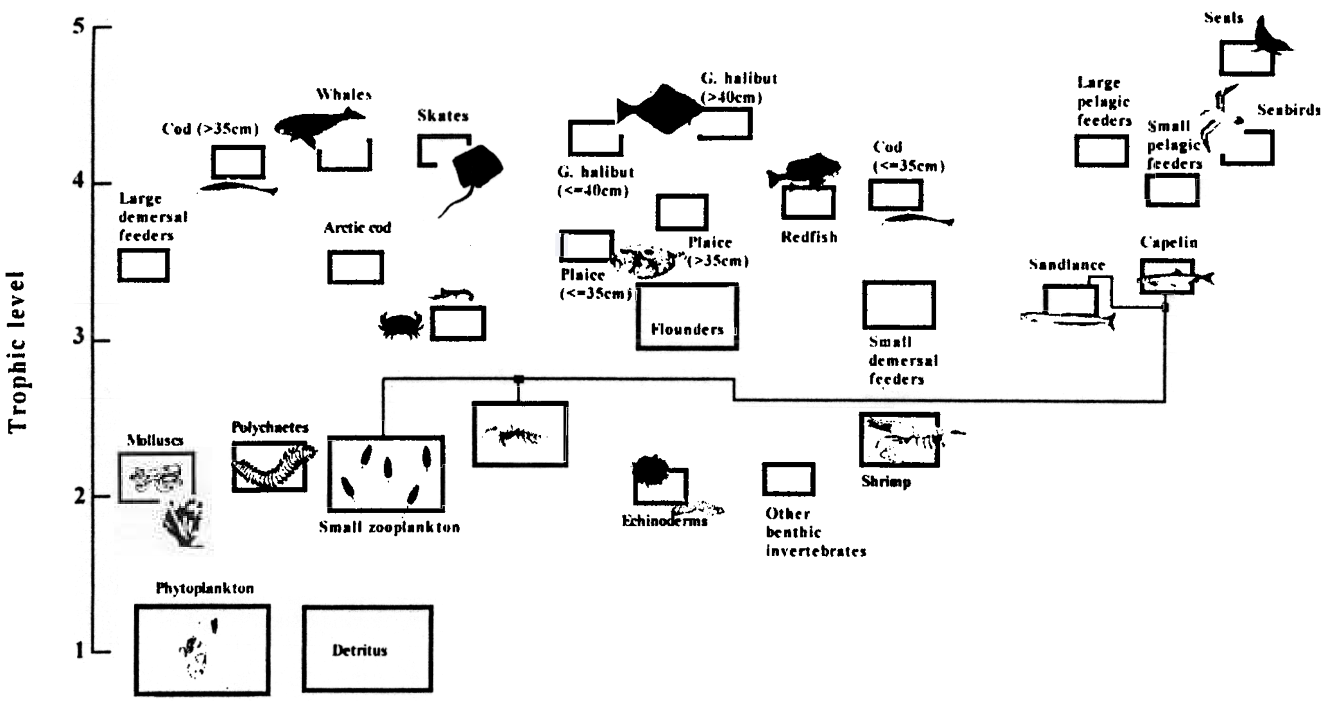

Figure 1: Mass-balance trophic model of the marine ecosystem on the Newfoundland and Labrador shelf in the late 1980s (from Bundy *et al.*, forthcoming). The boxes represent functional groups (species or groups of similar species), the lines the flows of energy between these groups (here limited, for simplicity's sake, to the flows to the box for sandlance, an important forage fish). The boxes, whose sizes are roughly proportional to the logarithm of the relative biomass therein, are arranged by trophic levels, with the top boxes representing top predators and conversely.

ing) for the Newfoundland-Labrador shelf, and by A. Beattie (1999) for the British Columbia shelf, using the Ecopath mass-balance approach and secondary data from a variety of sources.[1] In these models, biological production (a flow of biological matter, or "biomass") for each species or functional group (i.e., a "box" in Figures 1 and 2) is set equal to its consumption by other groups in the system, plus its fisheries catches and other losses from the ecosystem. Such mass-balance is achieved only when a good understanding of the feeding (or "trophic") interactions in the system has been reached. At this stage, the outputs of the models can be used for several inferences, notably on the position of each group within the food web, expressed by their "trophic level" (Y-axis in Figures 1 and 2).

Historical landing data were gathered by N. Newlands and M. Power for the Newfoundland-Labrador shelf (representing the east coast) and by S. Wallace for British Columbia. Both data sets rely on statistics assembled by the Department of Fisheries and Oceans (DFO), complemented with historic data from provincial records and various publications documenting specific fisheries.[2] An effort was made to include catches from small-scale fisheries, and thus to work against a widespread bias, which tends to undervalue their contribution (Pauly, 1997). Note that we differentiate, where appropriate, "landings," i.e., fish and invertebrates landed by fishing vessels, from "catches," which also includes fish killed and discarded by the fishing operation and for which time series usually are lacking.

The present nominal "value" of the fisheries was obtained by multiplying the landings by current prices, by species groups. Our analysis does not aim to establish how the fisheries compared with other sectors in the past, but to examine earlier catch compositions in terms of the commercial values they would currently obtain.

The impacts of the fishery on the ecosystem were evaluated with reference to the mean trophic level of the species groups in fisheries landings ($\bar{T}L_I$) using $\bar{T}L_I = \Sigma(y_j \cdot TL_j) / Y_i$ where y_i is the catch of species group j in year i, $\bar{T}L_j$ is the trophic level of species group j, obtained from the Ecopath model of the appropriate coasts (Figures 1, 2), and Y_i is the total catch of all species groups in year i. A few estimates were taken from FishBase 98 (Froese and Pauly, 1998)[3] for groups whose trophic levels were not estimated by one of the two models in Figures 1 and 2.

RESULTS

While similar in their basic architecture, the models in Figures 1 and 2, representing the east and west coast ecosystems, respectively, differ in two important attributes:

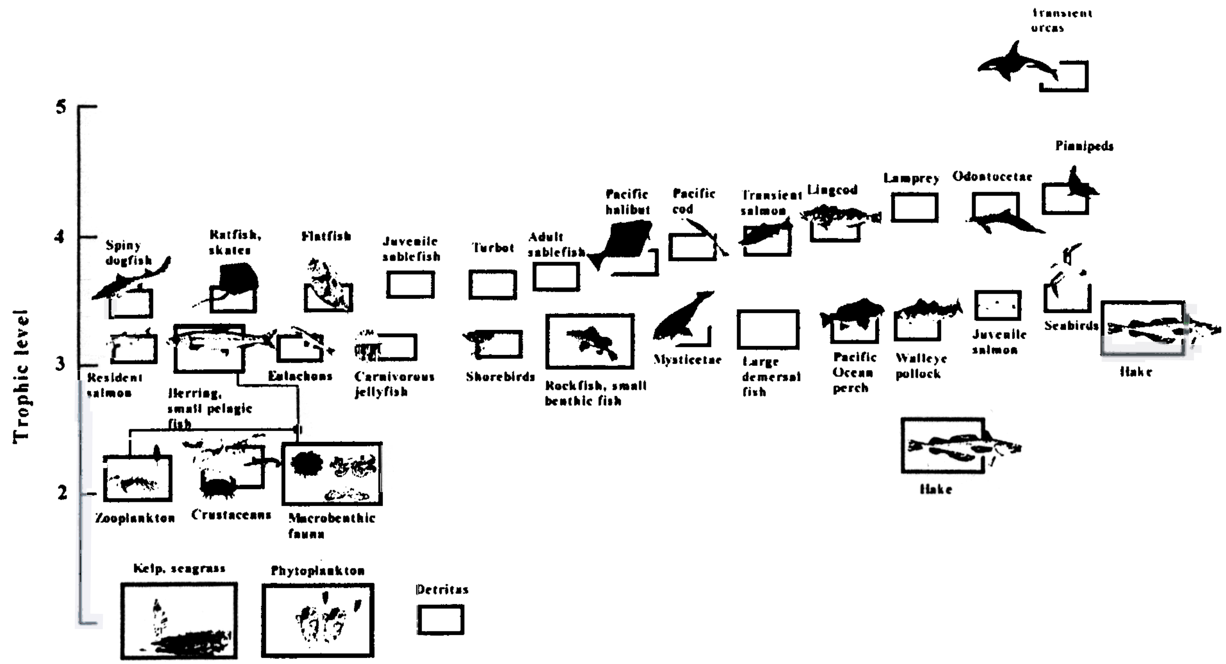

Figure 2: Mass balance trophic model of the marine ecosystem along the coast of British Columbia in the early 1990s, derived by combining models of the southern B.C. Shelf (Pauly and Christensen, 1996) and the present-day Strait of Georgia (Dalsgaard *et al.*, 1998) with the Hecate model of Beattie (forthcoming). The boxes represent functional groups (species or groups of similar species), the lines the flows of energy between these groups (here limited, for simplicity's sake, to the flows to the box for herring, an important forage fish). The boxes, whose sizes are roughly proportional to the logarithm of the relative biomass therein, are arranged by trophic levels, with the top boxes representing top predators and conversely.

a The top predators on the west coast are transient killer whales, feeding on other marine mammals. Such predatory control of, for example, the seal population is lacking on the east coast.

b. The fisheries on the west coast exploit a larger variety of commercial species than the east coast fishery, which relied predominantly on cod during the period covered by the model in Figure 2.

The state of both of these ecosystems, as represented in Figures 1 and 2, is much modified from their previous configurations. This is due to industrial fisheries that saw, in this century, enormous increase of their catching power and on both coasts overwhelmed the small (artisanal) fisheries. Also, we see a shift by the Canadian-based industrial fisheries from species formerly abundant to other species (small fishes, invertebrates) that they had previously spurned (see Table 1). (Note that some of these species may have been important in the past, e.g., to Aboriginal communities.) However, the time series in Figures 3a and 3b also reflect management interventions (notably federal government support for industrial fisheries development), and not only changes in market conditions. Thus, to enable interpretation of these time series, brief narratives on the history of these fisheries are given below. These narratives also allow the reader to interpret the trends in Table 1, and Figures 3c-3f, representing changes of mean trophic level of landings from the waters around Newfoundland-Labrador and along the B.C. coast, from the turn of the century to the present. As will be seen, these changes raise serious issues of ecosystem justice, as defined by Brunk and Dunham (this volume).

Newfoundland Fisheries

As might be seen from Figure 3b, the fishery was more or less stable until mid-century, with only small changes in the mean trophic level of the landings (Figure 3d), driven mainly by changes in the (small) landings of fish other than cod, the dominant species in Newfoundland-Labrador (Table 1). Indeed, all the fishery did, in the first half of the century, was continue with its relatively sustainable form of exploitation, established hundreds of years earlier (see Ommer, this volume), which involved access only to the shallow part of the cod stock, using traps, a very selective artisanal gear.

Then after World War II, an increase in fishing and the 1948 introduction of pair trawling (an industrial gear) led to the first noticeable decline in mean trophic level, due to an increase in the landings of species other than cod (Figures 3d, 3b).

Table 1: Estimated Trends of Value of Annual Commercial Landings for Newfoundland/Labrador and British Columbia (millions of 1996 CAD)

Species Groups	Price ($/kg)[a]	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s
	0.96	228	239	231	221	318	733	456	333	66
	0.68	16	4	4	4	15	51	91	75	38
	0.13		0	0			7	4		
	2.15	7	7	7	6	9	5	54	65	153
	(1.34)	252	250	243	232	342	796	605	474	258
	2.82	202	219	221	197	216	178	179	219	194
	0.41	6	9	8	14	10	23	21	32	62
	1.28	32	94	138	171	199	201	69	46	50
	4.05			5	12	27	33	30	60	110
	(1.30)	241	323	373	394	451	434	299	358	416

Trends are shown as decadal averages. Historical values were calculated assuming 1996 prices can be applied to earlier landings. Note large current value of invertebrate landings, which mask the effects of the ecosystem disruption their exploitation implies.

a. Price (CAD/kg) for 1996: Department of Fisheries and Oceans (DFO): www.ncr.dfo.ca

b. Sources of historical landings off Newfoundland/Labrador: Myers, Bridson, and Barrowman (1995); for 1900-60, major species landings trends were scaled to 1960 estimates (Leacy, Urquhart, and Buckley, 1993); 1960-96: NAFO Statistical Bulletins, subareas (2J, 3K/L/N/O, 3Pn/s, and 4R); 1972-96: DFO, Web site.

c. Historical landings for 1900-96 from Myers, Bridson, and Barrowman (1996), NAFO subareas (2J, 3K/L/N/O, 3Pn/s, and 4R);

d. Historical landings database for 1900 to 1972 by S. Wallace, based on governmental and non-governmental sources; for 1972-96: DFO, Web site.

With Confederation (1949), Canada took control of marine fisheries. Offshore foreign fishing fleets greatly expanded their capacity, especially from 1960 on. Radar and other electronic navigational aids, echo sounders, and nylon multifilament and monofilament nets were developed and put into use. This was a time when it was thought technology not only held all the answers, but *was* the answer. Consequently, with the establishment of the 200-mile exclusive economic zone (EEZ), Canada created, largely through federal subsidies, a new Canadian offshore factory-freezer trawler fleet, and began to catch previously unexploited species (often the prey of traditional resource species).

These new fisheries, targeting groups tending to have low trophic levels, led to a strong decline in mean trophic level throughout the 1980s. This continued in the 1990s, e.g., through the opening in 1993 of a fishery for Icelandic scallops. Cod landings were initially high in both the inshore and offshore sectors, but declined, especially in the inshore sector, as the 1980s wore on. When the ground fishery collapsed at last in the early 1990s and the commercial Atlantic salmon fishery was closed in 1995, only the fisheries targeting organisms low in the food web – especially invertebrates – remained active (Table 1; Figure 3d), while thousands of small- scale operators and fish workers lost their jobs.

The dominant trend here is one of "modernization and development" driving the traditional resource species (cod) down, and new, previously neglected, non-commercial species low in the food web being turned into "resources." As fishers increased their debt load to finance the new technologies deployed in this process, they needed not only to maintain their incomes, but even to increase them so as to meet payments. Governments, through various subsidization schemes, encouraged this development of "underutilized" species, seeing them as a solution to the problem posed by decreasing incomes, "excessive" numbers of fishers, and processing plants operating below capacity. This was intensified by demand in the Japanese market for roe, met by new capelin and lumpfish fisheries, and by the 1980s craze for fish-as-health-food, which caused market prices to rise. Market forces, thus, were another strong incentive to exploit new species.

What has been overlooked is that these "new" species had, in fact, always been part of the resource system, but as part of the diet of the traditional species. Thus, having first competed with marine mammals for their fish prey, we are now competing with cod and similar fish for their invertebrate prey.

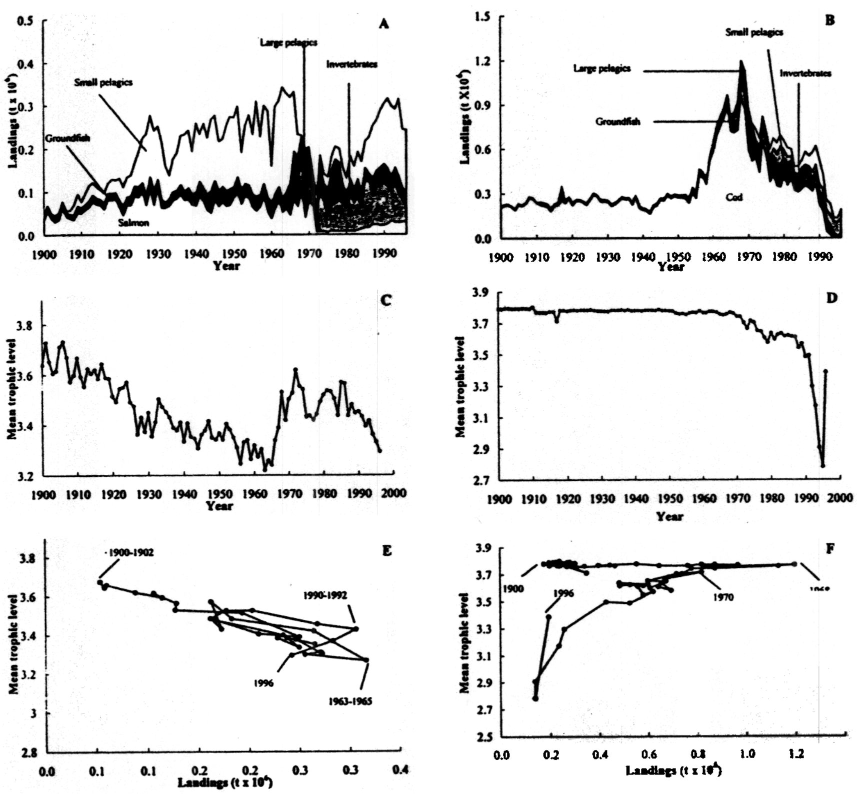

Figure 3: Major trends in Canadian fisheries, 1900-96. **a**: trends in B.C. catches (landings and discard data assembled by S. Wallace); **b**: trends in landings, Newfoundland/Labrador (N. Newlands); (**c** and **d**): trends of mean trophic level, based on methodology presented in text; (**e** and **f**): mean trophic level vs. landings (a three-year moving average is used for clarity in e). Refer to Table 1 for details on data sources and text for interpretation of these trends.

British Columbia Fisheries

The coastal resources of B.C. have been used by humans for thousands of years, and the structure of the marine ecosystem observed today is largely an artefact of past human exploitation.

Steller's sea cow was widespread in the North Pacific as recently as 20,000 years ago. By 1741, when this animal was first described in the scientific literature, it had disappeared from essentially all but a small area of marginal habitat in the Commander Islands, near Kamchatka, Russia. This decline cannot be explained by natural predation or climate changes (Domning, 1972). Rather, due to the ease with which these animals could be approached and harpooned, early human hunters had caused the extinction of these animals throughout most of their range. The sea cow, being the only large animal known to eat macro-algae (kelp), would have been a keystone species along the B.C. Coast, and its removal should have strongly impacted nearshore ecosystems (Pitcher, 1998). Thus, by the time Europeans arrived on the coast of what later became British Columbia, the ecosystem was already structured by human influence. However, the changes that then followed were massive and swift, far in excess of any conceivable impact due to the earlier extirpation of the sea cow.

Commercial landings on the west coast have been recorded since 1873. Three major periods can be distinguished in the time series of landings (Figure 3a) and, consequently, in the mean trophic level of the landings (Figure 3c). The period from 1875 to the turn of the century (not shown on Figure 3) represents the initial transition of the fishery from a primarily Aboriginal subsistence catch that included both fish and invertebrates to a commercial fishery by European settlers. This period is characterized by a rapid expansion of salmon, dogfish (a small shark), and halibut fisheries, the beginnings of herring exploitation, whaling, and the killing of large numbers of fur seals. This period also saw a disfranchisement of the earlier, largely sustained Aboriginal fisheries, notably the river-based ("terminal") fisheries for salmon (Glavin, 1996).

The second period, from the turn of the century to the mid-1960s, was dominated by large-scale reduction (fish meal and oil) fisheries for small pelagic fish. From around 1910, the rapid expansion of the reduction fisheries resulted in enormous landings of herring and pilchard (Figure 3c). Pilchard landings, for example, increased from 60 tonnes to 78,000 tonnes in only 12 years. Until they crashed, these catches of small fish feeding low in the food web caused a strong decrease in average trophic levels, down to a minimum in the early 1960s. However, at least in the first part of this period, considerable amounts of salmon and halibut were still being landed.

The third period saw the overall level of landings near historic highs. Hake is the species group contributing most to this, but invertebrates are being landed in increasing quantities (see Figure 3a), paralleling developments around Newfoundland-Labrador (see also Table 1). Here, as in Newfoundland-Labrador, the provincial government added to the federal government's implicit strategy of industrializing the fisheries a second (regional development) component, aiming to create, through various subsidies, new fisheries for previously unexploited species. This strategy, currently part of regional diversification in B.C., leads straight down the food webs.

DISCUSSION

Understanding the long-term ecological impacts resulting from multi-species or even from single-species fisheries is a difficult task. Many factors influence populations and ecosystems, making the determination of precise causal relationships illusory. Indeed, the best we can do is establish "propensities," i.e., "weighted possibilities, capable of producing upon repetition, a certain statistical average" (Popper, 1995). And we have problems even then, given that repetition is not possible in a historical development such as the sequential depletion of fisheries resources. Still, we can assume that ecosystem impacts did result from the rapid removal of important components of the shelf ecosystems discussed here, e.g., when the B.C. herring fishery of the 1960s caught 258,000 tonnes in a single year. Removal of the most important forage fish along the B.C. coast is bound to have had a huge impact on the populations of higher trophic level species that feed primarily on herring (see Figure 2; see Jones, this volume). Similarly, the removal of high amounts of capelin, the primary forage fish on the east coast (Figure 1, and see Neis and Morris, this volume), is bound to have had an impact on the maintenance of past cod populations – just as the removal of invertebrates is likely to affect the recovery of the present, much depleted population. While detailed data do not exist to allow the testing of this and related hypotheses, perfect knowledge is not required to assess the overall trend of human impact on marine ecosystems. In the words of Ehrlich (1994), "it is not necessary to have counted, named, and established measures of similarity among the grains of sand, pebbles, shells, and rocks on a beach to determine for practical purposes the beach is eroding."

Monitoring changes in mean trophic levels of fishery landings is a method to measure the erosion of ecosystem integrity (Pauly et al., 1998). To interpret trends in trophic levels properly, we must, however, consider the fact that they reflect only imperfectly the relative abundance of low- and high-trophic-level organisms in the ecosystems. Thus, estimates of mean trophic levels will drop if low-trophic-level species start to become exploited, even if the high-trophic-level species previously dominating the landings do not decline in absolute terms.

Still, the key reason why invertebrates on both coasts are increasingly targeted is because there is not much else for the overcapitalized fleets to exploit. Hence, the relative increase of these invertebrates in the landings does confirm, for Canada, the global trend toward "fishing down marine food webs" (Pauly et al., 1998).

Extrapolating this trend into the future is a straightforward task. We shall see more invertebrate fisheries opening up, more phyla previously considered gross being found grand, and when these fisheries collapse, more hand-wringing, by fishers and managers alike, about the need to reduce fishing effort to some "sustainable" level – as if "sustainability," a questionable concept in the first place (Frazier, 1997), had ever been achieved by an industrial fishery (see Ludwig, Hilborn, and Walters, 1993; Glavin, 1996).

This situation obviously raises issues of distributive justice (see Brunk and Dunham, this volume, for a definition). Notably, the fishing pressure generated by a single industrial vessel is so large that it can substitute for many individual small-scale fishers, whether Aboriginal or not, or whether catching fish for a living or for fun, as sport fishers do. Hence, encouraging the development of industrial fisheries, as the federal government of Canada did in the last decades, was in effect a decision to phase out small-scale fishing, including that by people – Aboriginal and non-Aboriginal – for whom fishing defines their cultural identity (See Jones and Williams-Davidson, this volume). This decision does not appear to have been discussed with those who were affected by it.

In the meantime however, this and related issues of distributive justice, though they still are those one hears about most in the media, are being rendered increasingly irrelevant, on the ground, by the ongoing erosion of successive resource species and the unravelling of their supporting ecosystems. Indeed, the issue at hand is now largely one of "productive justice" (see Brunk and Dunham, this volume), i.e., whether we want to let shelf ecosystems be productive entities, capable of meeting the need of a variety of users and of maintaining themselves as well. The alternative, obviously, is to let the present trends continue.

The former choice implies a serious attempt to rebuild stocks by closing parts of the ecosystems to all fishing (Guénette, Lauck, and Clark, 1998; Pitcher and Pauly, 1998) and being serious about our stewardship of their exploited parts (see Roach, this volume). We have no delusions of this happening in the near future. However, values do change, and the Canadian public at large may wonder why their government, as a signatory to various conventions meant to protect marine biodiversity, not only allows these trends to continue, but blesses them with subsidies. Moreover, the countries that will manage to maintain the integrity of their coastal ecosystems, i.e., to practise "ecosystem justice" (Brunk and Dunham, this volume), may end up as economic winners when the others, having let these trends erode their resources, find themselves surrounded by seas empty of fish.

NOTES

1. The Ecopath mass-balance approach and software are documented in Christensen and Pauly (1992); further references and applications may be obtained at http://www.ecopath.org, from which the software may also be downloaded. The Ecopath home page contains, as well, the files used to generate Figures 1 and 2 and information on their data sources.
2. These catch data are available from S. Wallace (B.C. coast) and N. Newlands (Newfoundland-Labrador coast) (see www.fisheries.com for further information).
3. The FishBase home page (www.fishbase.org) may be visited for details on trophic level estimation and for biological information on species of fishes included in the models and/or exploited by Canada's marine fisheries.

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