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Protecting endangered whales by better fishery management

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~~Main text (max 1000 words):~~

The North Atlantic right whale is one of the most critically endangered marine species. Drastic overexploitation has driven this large, slow-swimming baleen whale to virtual extinction in Europe, while a small remnant population of ~350 individuals remains on the US and Canadian east coast. Although this species has been protected for 70 yrs, recovery has been slight and extinction is still looming due to accidental mortality from shipstrikes and fishing gear (Figs. 1A, B)*(~~1~~1)*. At least 72% of examined whales show evidence of entanglement, predominantly with lobster fishing gear from both the inshore and offshore fishery, and this percentage has been increasing over time*(~~2~~2)*. At the same time, the U.S. lobster fishery is severely overexploited*(~~3~~3)*. Here we argue that endangered whale species can be protected and the fishery can benefit simultaneously by a large reduction of lobster traps used, a classic win-win situation.

Lobster catches have increased substantially over the last 20 yr, mostly in the Gulf of Maine, the world's most important lobster producing area (Fig. 1C). Hence, lobster has become one of the most important fisheries in the U.S. ($367 million, in 2004) and Canada (CDN$650 million in 2003). Along with the increase in catch came with an expansion of fishing effort, here defined as the total allowed number of lobster traps in the water per day. Traps are tied to the surface via a buoy line, and to other traps via a ground line, both of which can cause whale entanglement*(~~4~~2)*. This is affecting other endangered species too, principally fin and humpback whales, although their status is not as grave as right whales. In response to the statutory requirements to protect these whales under the Marine Mammal Protection Act and the Endangered Species Act, the National Marine Fisheries Service has implemented a so-called Take Reduction Plan for large whales in the northeast*(~~5~~4)*, though this plan has been very controversial with the fishing industry and elected officials over the past ten years. It mainly calls for fishing gear modifications such as weak links in lobster trap buoy lines. There also are area restrictions, where only modified gear may be used, with an option of gear to be removed if deemed necessary. The plan does not include direct fishery management measures. Hence fishing activity is modified but not reduced, and whale entanglement is still an increasing problem.

We contrasted total fishing effort, taken from published reports, between the American and Canadian side of the Gulf of Maine. The increase in catch over time has been similar, although relative increases have been higher in Canadian waters (Fig. 1C). Eighty percent of the Canadian catch in the Gulf of Maine comes from lobster fishing area (LFA) 34 in southern Nova Scotia*(5)*~~6~~. This area is restricted to a winter fishing season, using only about 12% of the traps that are used in Maine on a year-round basis. Though some of the gear in Maine is voluntarily removed from the water during the winter, when whales are rarely present in the area, -this can not be quantified with the current monitoring system. Considering that Maine has about 30% higher catches than LFA 34, a year-round season, and 8-9 times more traps in the water at any given time, we derive that the number of traps in Maine is 13 times greater than in LFA 34 to harvest the same catch (Table 1).

Consideration of the pattern of whale sightings through the year (Fig~~ure~~. 1D) provides a basis for selecting lobster fishing seasons that should keep the risk of entanglement low. Only 7% of the right whale sightings, corrected for effort, occur during the LFA 34 fishing season (last Monday in Nov. to 31 May ~~31~~) north of 43~~.5~~°N (Figs. 1D, S~~upplementary figure~~ 1). Thus, each lobster caught in the Canadian fishery has less than 1% the impact of the Maine fishery on right whales. That is, if Maine would generally restrict its fishing season to 6 months and reduce the number of traps in the water 10-fold, the same amount of lobster could be landed, with greatly reduced risk to right whales and other species. We note that the U.S. lobster fishery in the Gulf of Maine also includes vessels from other New England states. Similar figures are expected to apply to these states.

Our estimates of effort reduction in the Maine lobster fishery are conservative because the present fishing mortality in both Maine and Canada is typically 4 times that needed to achieve optimal long-term yield (supporting online text, Figs. S2A,B~~see supplement~~). In the Canadian lobster fisheries, 50% of the catch is landed in the first month of the season (Figs. 1D, ~~Supplementary figure S1, 2~~2A,B). Moreover, endangered whales are absent or at low abundance during the winter season (S~~upplementary figure 3~~1). Limiting fishing to a shorter season with low presence of endangered species does greatly reduce entanglement mortality. It has been argued that such measures may disrupt the year-round 'feeding' of lobsters with trap bait ~~which~~that might have contributed to the large increase in lobster populations. However, this notion is inconsistent with the even larger increase on the Canadian side of the Gulf of Maine that occurred in the absence of year-round fishing and with <8% of the effort. There are, of course, market considerations that may need to be considered in consolidating the fishery into shorter seasons.

This huge excess effort in the lobster fishery is characteristic of a global problem. Many shrimp fisheries have much larger effort than needed to obtain optimum yields*(~~7~~6)*, and represent a key conservation issue for endangered sea turtles and fishes caught as bycatch*(~~8~~7)*. Similarly, the global effort for tuna longline fisheries (~1.4 billion hooks in 2000) threatens turtle*(~~9~~8)* and sharks*(~~10~~9)* and may be much higher than needed to achieve optimal yields. The driving factor for overcapacity in the Maine lobster fishery and elsewhere is competition between fishermen and the absence of restraining regulations that would allow for the buildup of exploitable biomass. The situation is getting worse, as there has been an increase of over 1 million traps in Maine in the last 10 years (Fig. 1C). Interestingly, some Maine

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fishermen have taken steps to reduce overcapacity in order to maximize~~ing~~ profits and yields*(~~11~~10)*. On Monhegan Island, Maine~~E~~, the fishing season has been restricted to 180 days per year, which allows fishermen to pursue other incomes while lobster populations are rebuilding. A further economic advantage is that a targeted fishery outside the summer molting season yields a higher quality product and better prices.

We conclude that right whales as well as fishermen would benefit from seasonal closures and trap limits at or below Canadian levels (currently less than half of US trap limits). The comparative history of the two sides of the Gulf of Maine suggests that restraining fishing effort is economically viable and will help to save endangered large whales from future declines and extinction.

Figures and table:

Figure 1. A. Right whale entangled in lobster gear, Sept. 2004. B. Same whale, dead, April 2005. C. Lobster landings (solid blue~~red~~ line) and effort (dashed blue~~red~~ line) in Maine versus the Canadian landings (solid red line) and allowed effort since 1968 (dashed red line) in the Gulf of Maine Lobster Fishing Area 34. This plot does not show the movement of effort offshore since 1980~~ ~~*(5~~5~~)*. The effort in both Maine and Nova Scotia is the maximum possible; some fishers in both regions do not keep their gear in the water all winter. D. ~~The~~ C~~c~~umulative effort~~-~~-corrected right whale sighting frequency for the Gulf of Maine for three latitude bands: (a) North of 43.5°N~~ degrees~~ (red), b between 41.5°N and 43.5°N~~ degrees~~ (green), and (c) South of 41.5°N~~ degrees~~ (blue).

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Think about blue area for the Gulf of Maine.

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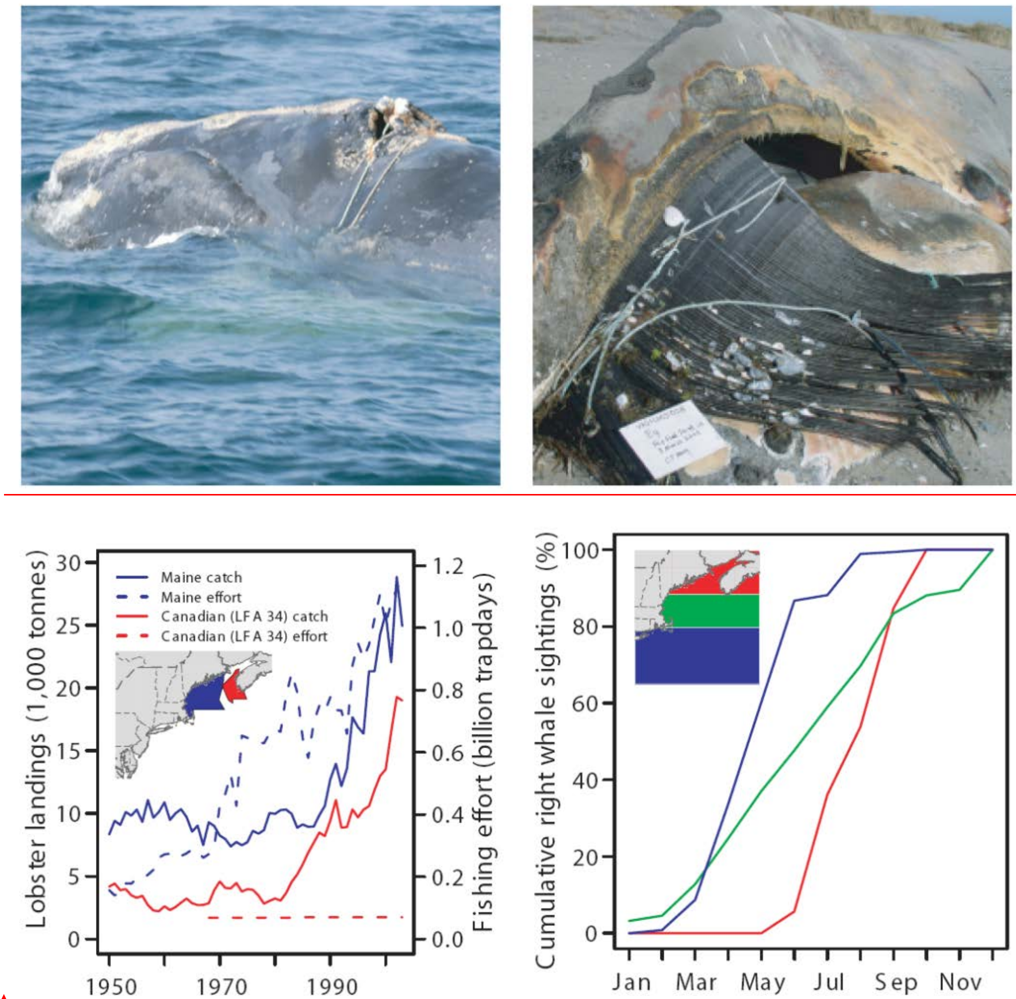

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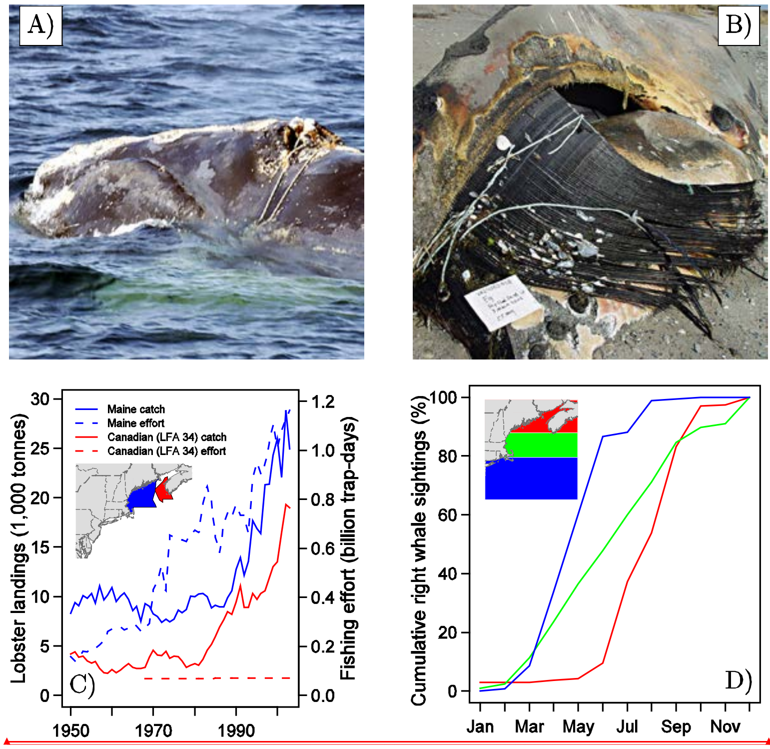

Table 1. Lobster fishing effort in Maine and LFA 34 (Canada)

	Maine	**LFA 34**	**Maine/LFA 34**
Landings (tonnes)	24,935	19,000	1.31
Traps	3,189,471	369,750 (fall) 394,400 (spring)	8.62 (fall) 8.09 (spring)
Season-days	365	185	1.97
Overcapacity in Maine compared to LFA 34			~13

Supplementary Figure 1: Right whale seasonal distribution in the Gulf of Maine.

Supplementary Figure 2: Cumulative catch during a restricted season in Canadian waters.

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1. S. D. Kraus *et al.*, *Science* **309**, 561 (2005).

2. A. Johnson *et al.* *Mar. Mam. Sci.* **21**, 635 (2005).

3. The inshore fishing mortalities in the two main US regions are 0.69 and 0.84 *(11)* while 0.2 achieves maximum yield per recruit *(12)*. The maximum economic yield would be achieved at a lower fishing mortality.

4. "Atlantic Large Whale Take Reduction Plan," (National Marine Fisheries Service, http://www.nero.noaa.gov/whaletrp/)

5. Department of Fisheries and Oceans, *Southwest Nova Scotia (Lobster Fishing Area 34)* (DFO Science Stock Status Report C3-62, 2001).

6. H. Onal, B. A. McCarl, W. L. Griffin, G. Matlock, J. Clark, *Amer. J. Agr. Econ.* **73**, 1161 (1991).

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8. R. L. Lewison, S. A. Freeman, L. B. Crowder, *Ecol. Lett.* **7**, 221 (2004).

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11. Atlantic States Marine Fisheries Commission, *Terms of Reference & Advisory Report to the American Lobster Stock Assessment Peer Review* (ASMFC Stock Assessment Report No. 06-03, 2006).

12. M. J. Fogarty, J. S. Idoine, *Trans. Am. Fish. Soc.* **117**, 350 (1988).

We thank M. J. Tremblay, D. S. Pezzack, R. J. Miller, D, A. Robichaud and C. Wilson, for data and comments and the Lenfest Foundation for support.

Supporting Online Material
www.sciencemag.org
Supporting online text
Figs. S1, S2 ~~, S3~~

Seasonal distribution of right whales in the Gulf of Maine

Monthly effort-corrected relative abundance of right whales in the Gulf of Maine was estimated using sightings data from aerial and shipboard surveys (Fig. S1). The correction for effort was imperfect because many surveys were directed towards known right whale habitats.

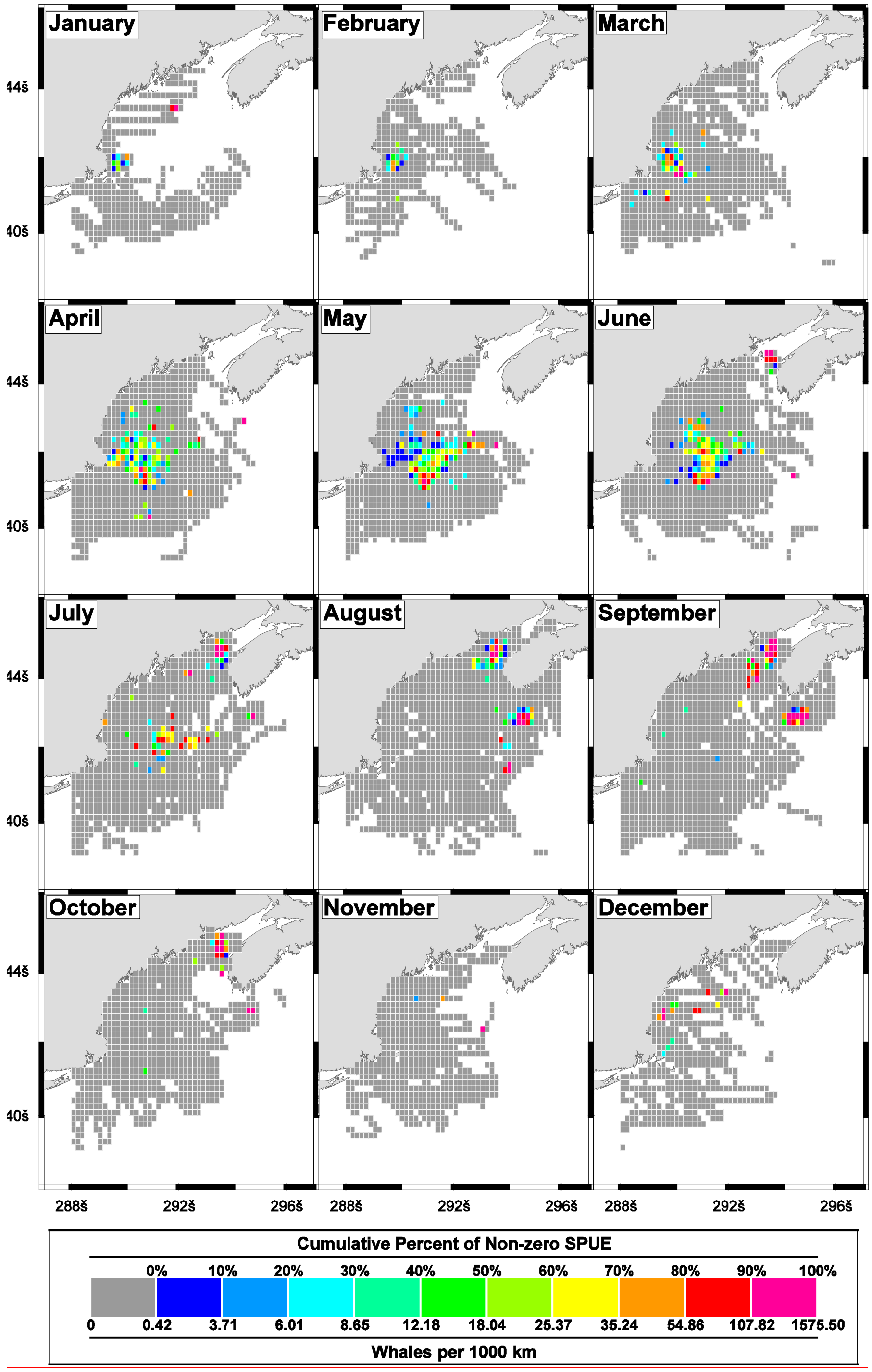
Cumulative lobster catches

Data from catch rates of individual fishers from 12 Canadian Lobster Management Areas (LFA's) were compiled and the cumulative distribution of the catches over the fishing season was calculated. Data from LFA 4, 13, 14 and 22 were extracted from published sources*(1,2)*. For the other regions, data from individual fisher's catches per day were summed for each day, and cumulated over each day of the fishing season (data provided by M. J. Tremblay, D. S. Pezzack, R. J. Miller, Department of Fisheries and Oceans, Halifax, Nova Scotia, Canada and David A. Robichaud, Department of Fisheries and Oceans, St. Andrews, New Brunswick). In all cases, the most recent data available were used, which was the 2004 fishing season except for the two published data sets.

The cumulative distributions are shown in two different formats: (1) in Fig. S2A the cumulative distribution is plotted against the day of the fishing season, e.g., all plots start the day before the fishing season starts, and (2) in Fig. S2B the cumulative distribution is plotted against day of year. Note that for LFA 35 and 36 there are two separate fishing seasons that occur before and after the main molting periods for lobsters in the Bay of Fundy region. Note the season for LFA 34 and 35 extend past Dec. 31, so the catches cover two calendar years and that in Fig. 2 the data wraps around to Jan. 1.

For all regions, except those with two fishing seasons, over 50% of the catch was obtained during the first month of the fishing season.

The fishing mortality that is optimal to obtain maximum yield per recruit is estimated around 0.2*(3)*. The fishing mortality for Canadian lobsters is estimated to be much greater, usually 0.8 or higher*(1,2,3)*. This implies that the catch should be reduced by about a factor of 4 to achieve maximum yield per recruit. However, the maximum economic benefit is found at a fishing mortality less than the maximum yield per recruit*(4)*. Thus to achieve maximum economic benefit the season needed to capture an optimal amount of lobsters would be approximately around 10 days in many Canadian lobster fisheries.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December
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292š
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Cumulative Percent of Non-zero SPUE
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90%
100%
0
0.42
3.71
6.01
8.65
12.18
18.04
25.37
35.24
54.86
107.82
1575.50
Whales per 1000 km

Fig. S1. Monthly right whale SPUE (sightings per unit effort, as number of right whales sighted per 1,000 km of survey track) in 10-minute cells off New England and Nova Scotia in 1978-2005. The distributions are based on all available aerial and shipboard surveys included in the North Atlantic Right Whale Consortium database. Valid survey effort is defined as track segments conducted with clear visibility of at least 3.7 km (2 nautical miles), sea states of Beaufort 3 or below, at least one observer on watch, and (for aerial surveys) altitude below 366 m (1200 feet). The total effort represented is over 822,000 km. Blank cells were never surveyed during that month (effort = 0), while gray cells were surveyed (effort > 0) but had no right whales sighted (SPUE = 0). Cells with whales sighted (SPUE > 0) were ranked into ten equal classes. Survey effort distribution is not random with respect to right whale distribution, since many survey programs are specifically targeted at known right whale habitats, but the SPUE method corrects as much as possible for this bias by scaling for the amount of effort expended in each 10-minute cell.

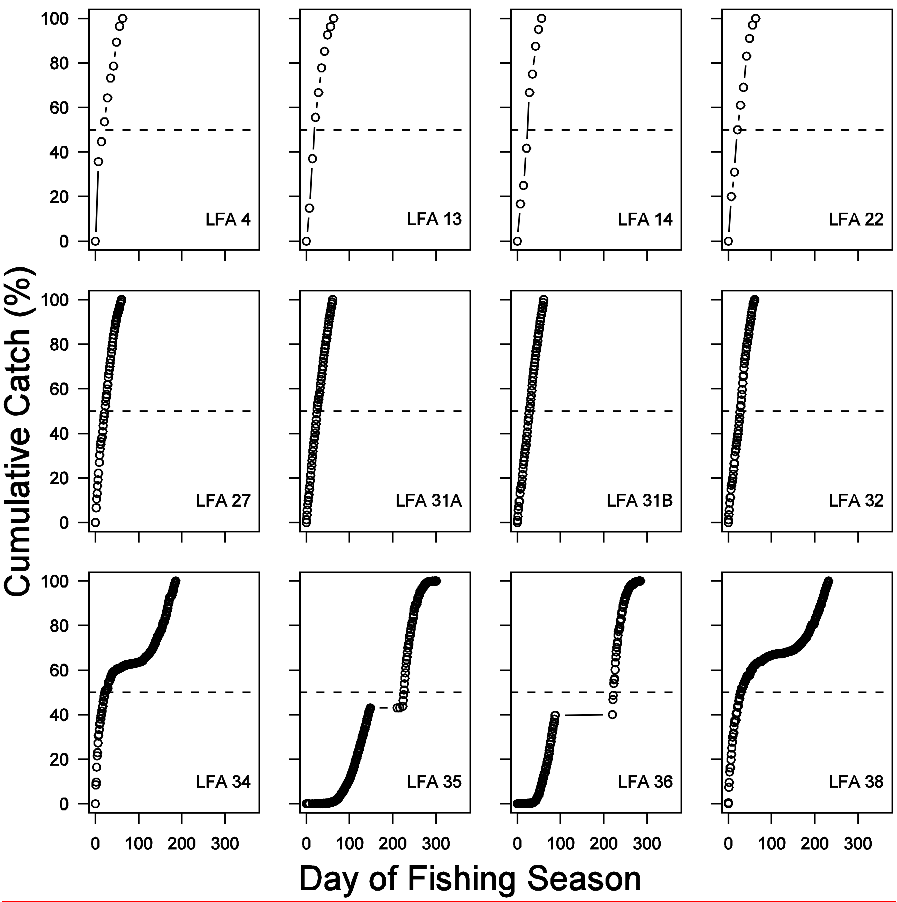

Fig. S2A. Cumulative catch for 12 Lobster Fishing Areas (LFA) in Canada plotted against day of the fishing season. The fishing seasons start at different times (see Fig. S2B), and in LFA 35 and 36 there are two seasons.

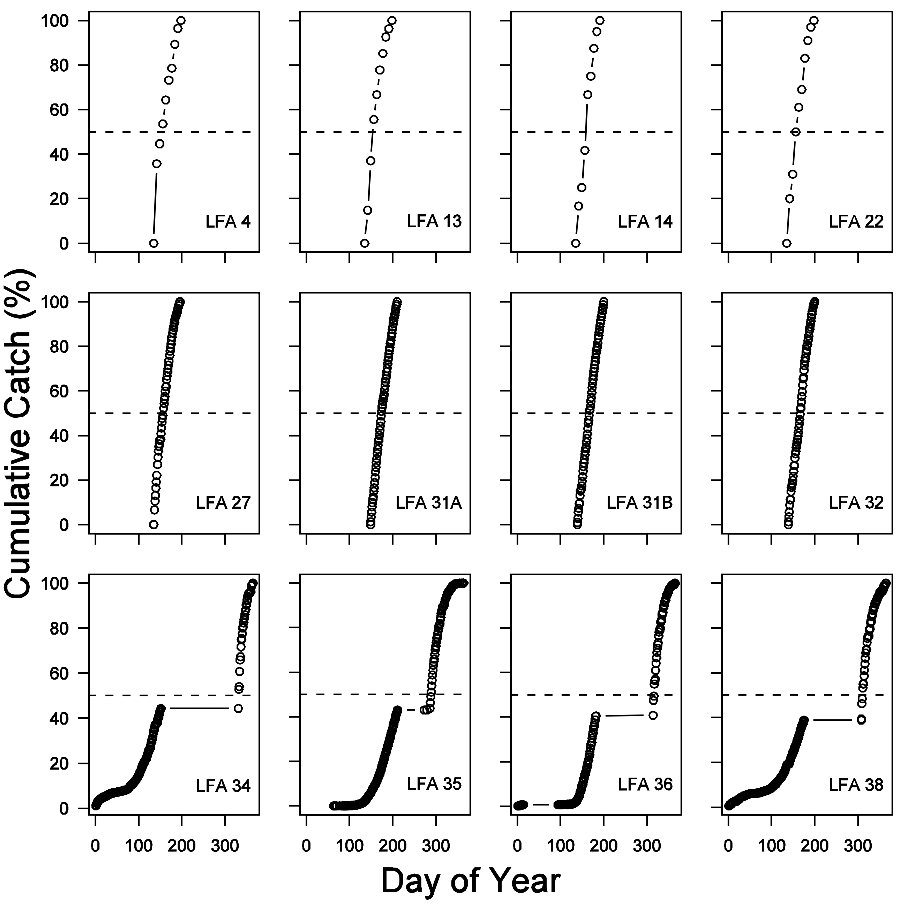

Fig. S2B. Cumulative catch for 12 Lobster Fishing Areas (LFA) in Canada plotted against day of year. The fishing seasons start at different times, and in LFA 35 and 36 there are two seasons. The dates of the fishing seasons are: LFA 4 - April 20 to July 15, LFA 13 - April 20 to July 5, LFA 14 - April 20 to July 15, LFA 22 - April 30 to June 30, LFA 27 - May 15 to July 15, LFA 31A - April 29 to June 30, LFA 32B - April 19 to June 30, LFA 32 - April 19 to June 20, LFA 34 - Last Monday in November to May 31, LFA 35 - Last day of February to July 31 October 14 to December 31, LFA 36 - March 31, to June 29 2nd Tuesday in November to January 14, LFA 38 - 2nd Tuesday in November to June 29. For a

Fig. S3. mMap of lobster fishing areas (LFA's) in Canada (from http://www.gov.ns.ca/nsaf/marine/map/lobarea.shtml). We will use a better plot that shows the offshore area 41.

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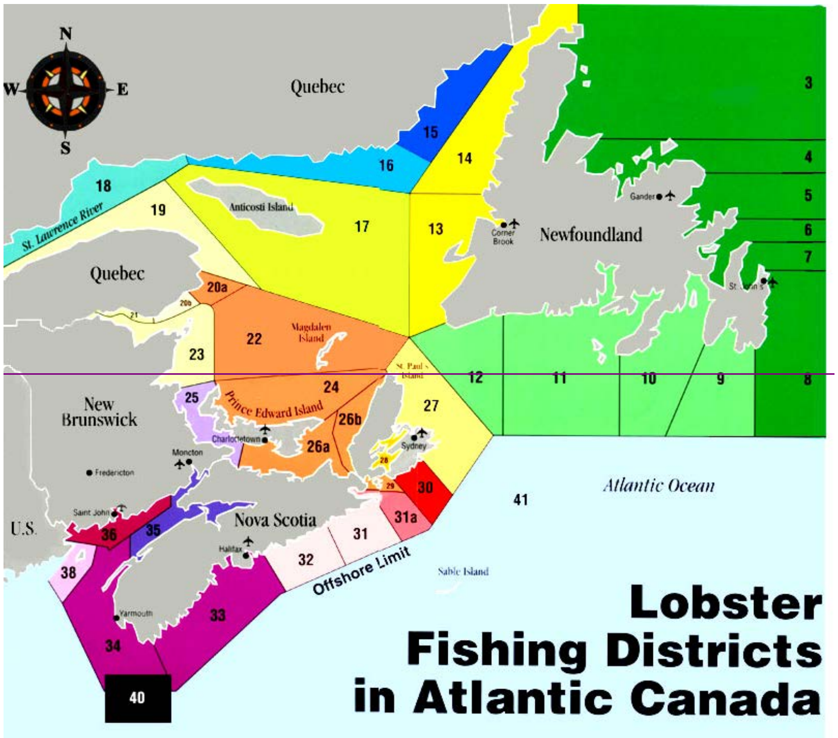

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[3] The inshore fishing mortalities in the two main US regions are 0.69 and 0.84 *(12~~ASMFS 2006~~)* while 0.2 achieves maximum yield per recruit *(13~~Fogarty 1995~~)*. The maximum economic yield would be achieved at a lower fishing mortality. ~~Atlantic States Marine Fisheries Commission (2006) Stock Assessment Report No. 06-03. Fogarty, M.J. and Idoine, J.S. 1988. Trans. Am. Fish. Soc. 117:350-362. Fogarty, M.J. and Gendron. 2004. Canadian Journal of Fish and Aquatic Sciences 61(8): 1392-1403~~

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