Lobster Sustainability Measures in Newfoundland: Are They Effective?

A plain language summary report compiled by
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Background: Why Do We Care?

The American lobster (*Homarus americanus*) fishery is a locally reliable inshore commercial fishery in North America with an economic value of CAD 550 million/year in Atlantic Canada. In Newfoundland, this provides 30 million/year in landed value and has considerable socio-economic value (2900 license holders) in rural communities throughout the province. The small boat lobster fishery is at once a regular source of income and part of the cultural integrity of coastal communities in Newfoundland.

In recent years concern about the sustainability of this fishery has risen because the percent of harvestable lobsters taken from populations each year is at least 75% in almost all Canadian stocks and in some areas rises to over 95%. The Fisheries Research Conservation Council concluded (FRCC 2007) that in the absence of science data on lobster stocks the fate of future stocks is uncertain if lobsters continue to be harvested at recent rates.

Several conservation initiatives were undertaken, with local support, to address these concerns and now form current management practice. These were closed areas [including federally designated marine protected areas (MPAs)], voluntary v-notching, a minimal landing size of 82.5 mm, and the adoption of a maximum size limit in four Lobster Fishing Areas (*i.e*., a slot fishery). The need for better scientific data on the effectiveness of these measures sparked the FFAW and fish harvesters in Newfoundland to collect data, contribute to the assessment of the stock, and propose a collaborative research project with Memorial University scientists in conjunction with CURRA, the Community-University Research for Recovery Alliance (www.curra.ca). With support from NSERC (Natural Science and Engineering Research Council) a 3 year project was undertaken to address questions being asked by harvesters: are these resource sustainability initiatives (v-notching, closed areas, and a slot fishery) effective?; and specifically, do these measures result in increased egg production and increased size/age distribution, which in turn increase egg production? To establish whether these measures have a science basis we used a central concept in population biology called "reproductive value" to evaluate the effectiveness of these measures. Reproductive value considers not only current egg production, it takes into account the expected future value of the individual to the population. Reproductive value allows us to compare the value of an individual as a commodity with its value to its population.

Goals of the Study

To determine whether these conservation measures are effective, we identified the following five goals:

(1) Calculate the reproductive value of lobsters in Newfoundland at each age and size throughout a lobster's life and calculate the ratio of reproductive value to landed value;
(2) Identify if differences exist in lobster fecundity at size and growth in locations from the northern end of the range in Newfoundland, to the southern end of the lobster's range (formerly Virginia, USA, now further north);

(3) Identify the effects of voluntary v-notching, a slot fishery, and closed areas (MPAs) on lobster size and reproductive value in Newfoundland;
(4) Estimate the spatial scale at which small closed areas increase reproductive value of lobster populations; and
(5) Promote stewardship on the basis of science.

Goal 1: Reproductive Value Relative to Economic Value

The first goal of this study was to calculate the reproductive value of lobsters in Newfoundland at each age and size throughout a lobster's life and calculate the ratio of reproductive value to landed value. The ratio of reproductive value relative to dollar value increased onward from reproductive maturity at age 7. The ratio of reproductive value to dollar value increased for large lobsters. For example, the ratio of reproductive value relative to dollar value at age 7 is 78, whereas at age 29 it is 1775. The future reproductive value at age 29 was roughly 120 times more than at age 7 (Xu and Schneider, in press).

Results: As lobsters grow larger, their value in terms of current and future egg production increases to a greater extent compared with their increase in dollar value. This is because egg production increases more rapidly than dollar value, measured at market prices of dollars per pound. Although harvesters lose the landed value of releasing large lobsters in the short term, this trade-off is beneficial in the long term because large lobsters make a far greater contribution to egg production than to landed value. Because reproductive value takes into account both the current and future value of a lobster it allows the value of an individual to its population to be compared with its value as a commodity.

Goal 2: Variation in Egg Production and Growth Rates

Quantifying reproductive value requires estimates of growth rates and egg production in relation to size. The second goal of this study was to identify whether differences exist in lobster growth and fecundity (egg production) at any given size and whether the relation of fecundity to size varies in any systematic way across the species range.

Egg Production
Egg number depended on female size; larger females produce more eggs. Traditional techniques to estimate eggs per lobster rely on removing all of the eggs from a lobster, an activity that requires special pleading (to remove eggs from only a “small” number of lobsters). Published estimates of eggs per lobster number in the tens of thousands through the range of the species, leading us to use this information to estimate egg/female throughout the range. We expected that the relation of egg number to female number would depend on water temperature and hence on latitude.

Results: Lobsters in more northern latitudes (Newfoundland) carry fewer eggs than lobsters further south (New England). A formula was developed to estimate the number of eggs per lobster throughout its entire geographic range (Currie and Schneider 2011) given its size. Lobsters in northerly latitudes (Newfoundland) carry fewer eggs than lobsters in more southern regions (southern New England) according to the following graph (Fig. 1).

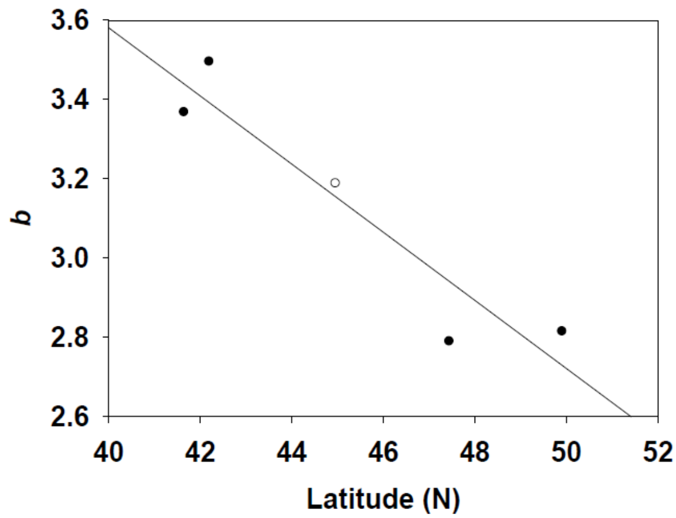

Figure 1. Relationship between fecundity parameter *b* and latitude. **For details see Currie and Schneider 2011.**

The fecundity parameter b allows egg number to be calculated from carapace length using the equation $F = aCL^b$, where F is fecundity (egg number) and CL is carapace length. If $b = 3$, then take the cube of the carapace length. If b is greater than 3 then the egg mass is bigger relative to lobster carapace length.

Value of result: The egg formula allows scientists to estimate egg number per lobster at any latitude north of New York without having to undertake expensive field efforts, or remove eggs from a sample of lobsters. This reduces the cost of research. The formula can be validated, if necessary, at any location by capturing a small number of lobsters.

Growth Rates

Growth in lobsters varies geographically and likely depends on several environmental factors, notably water temperature. To examine growth throughout the range, historical tagging data from over 15 studies were combined with current data from the west coast of Newfoundland.

Results: Growth rates, based on a commonly used formula, the von Bertalanffy growth curve, were found to decrease with increasing latitude and depend on temperature. A formula was developed that can be used estimate the von Bertalanffy growth rate (k) of lobsters at any location based on latitude (Fig. 2; from Raper 2011).

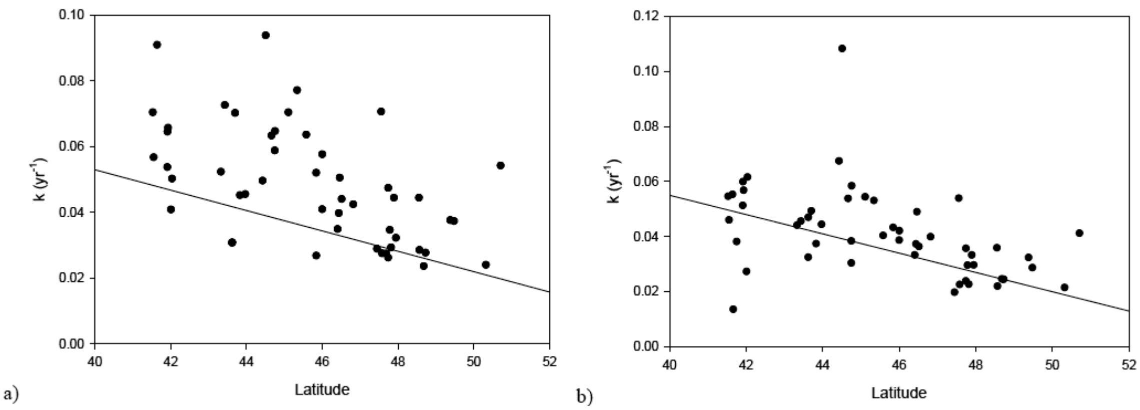

Figure 2. Relationship of von Bertalanffy growth parameter *k* to latitude for (a) male and (b) female American lobsters, with regression lines weighted by the inverse of the variance. R^2= 0.21 and 0.41, respectively. Graphs from Raper 2011.

Value of result: Growth rates can be estimated at any location in the range of this species, based on all of the available data, which are extensive. This reduces the need for new tag-recapture studies, which are time and resource intensive.

Goal 3: Efficacy of v-notching, a Slot Fishery, and Closed Areas

The third goal of this study was to determine whether voluntary v-notching, closed areas (MPAs), and a slot fishery increase lobster size and so increase egg production and reproductive value.

V-notching

V-notching increases egg production by protecting females the year after releasing eggs, when eggs are not yet visible on the underside of the animal. A v-shaped notch is cut at a defined location on the tail (the right uropod) of female lobsters that are carrying eggs when caught. It is illegal to land v-notched lobsters giving these mature females a chance to reproduce more than once. The practice is voluntary. The effectiveness of v-notching on egg production per female was assessed in lobster fishing areas on the east coast (Eastport, Leading Tickles, Gander Bay, Summerford, and Random Island) and west coast (Shoal Point and Trout River) of Newfoundland.

Results:

(1) V-notched lobsters were on average larger than those not v-notched. (Fig. 3; top and middle graph). This difference is due to the opportunity for growth, once a lobster produces eggs.

(2) The increase in size resulted in a substantial increase in egg production (Fig. 3; bottom graph) (Whiffen 2010).

(3) V-notching increased reproductive value by 18.3% (Xu and Schneider, in press). This increase is due to the opportunity for growth and consequent increase in future egg production, taking into account future mortality.

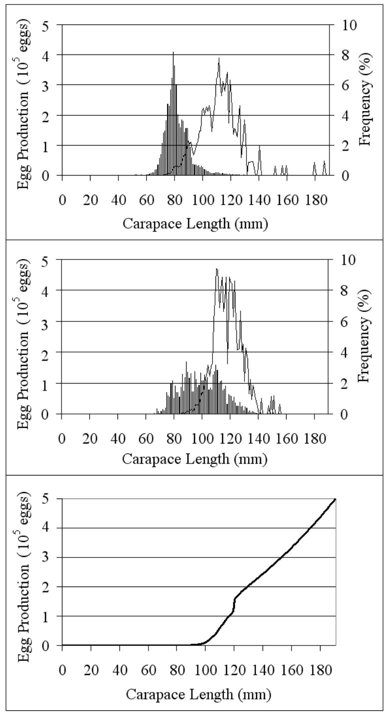

Figure 3. Egg production and number of females in each size class of non-v-notched lobsters (top) and v-notched lobsters (middle) and egg production/female (bottom). Shaded area represents number of females by size class and white area represents egg production by size class. Graphs from Whiffen 2010.

Value of results: V-notched lobsters accounted for 42% of the estimated egg production even though they accounted for only 6.8% of the catch. This supports the science basis for voluntary v-notching as an effective sustainability measure.

Slot Fishery

A slot fishery protects large lobsters as well as immature lobsters. A minimum legal size (82.5 mm carapace length in Newfoundland) allows lobsters to reproduce at least once. The upper limit on landing size of 127 mm in Newfoundland protects large lobsters, which are capable of producing far more eggs than small lobsters. The purpose of a slot fishery is to increase the number of lobsters that reach reproductive maturity (through a minimum landing size) and increase the number of large lobsters in a population (through a maximum landing size); both restrictions aim to increase the egg production in a population and so increase overall lobster stock biomass and harvest.

Results: The slot fishery on the west coast of Newfoundland (minimum landing size 82.5 mm and maximum landing size 127 mm) increased reproductive value by 16.8% (Fig. 4) compared with a minimum size restriction only. Taking lobsters greater than 127 mm reduces the percent increase in reproductive value (Fig. 4). Modified slot fishing (protection below 82.5 mm and in a window, between 100 and 129 mm) was less effective resulting in an average increase of 8.7% in current and future egg production. Narrower windows (between 115 and 129 mm and between 125 and 139 mm) were still less effective in increasing reproductive value (Fig. 4) (Xu and Schneider, in press).

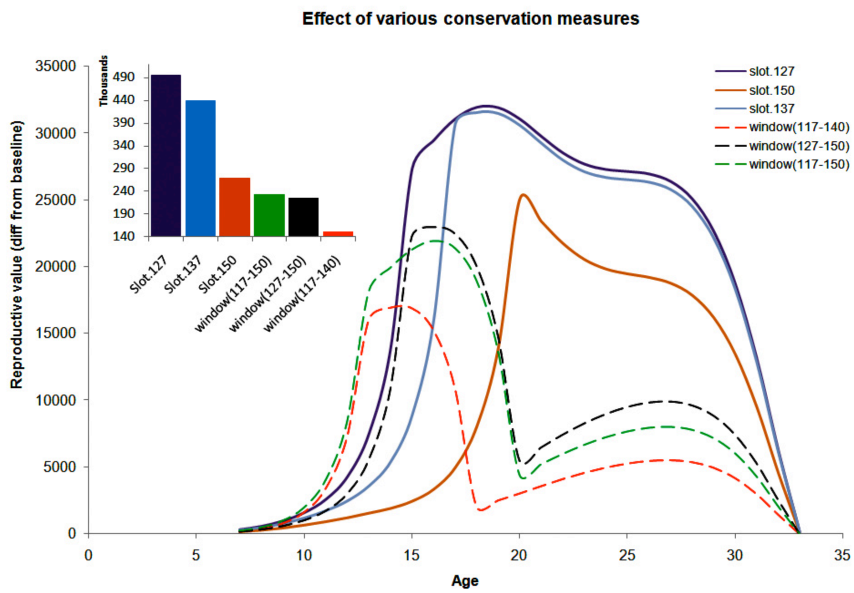

Figure 4. Effects of slot fishing and modified slot fishing (slot fishing with windows) on reproductive values.

Closed Areas (MPAs)

In addition to management regulations to control fishing effort (seasons, trap limits, minimum size limits), local groups have initiated several lobster closed areas, where fishing is prohibited, as a measure to increase stock sustainability. The goal is to protect lobsters from harvest in a small area, allowing them to grow bigger and reproduce, thus seeding nearby fished areas with larvae and increasing catches by adult spillover into adjacent areas.

In a Master's thesis (2010) associated with this project, Roanne Collins found that in two closed areas (Duck Island and Round Island at Eastport in Bonavista Bay), over a 12-year period, female numbers, size, and hence eggs per female inside both closures consistently exceeded that in adjacent areas (Fig. 5). For male lobsters, the difference in size was even greater than that of female lobsters. Over time there was an increase in the mean size of lobsters in the areas adjacent to the closures, which could be due to a spillover effect from the closure (Collins 2010).

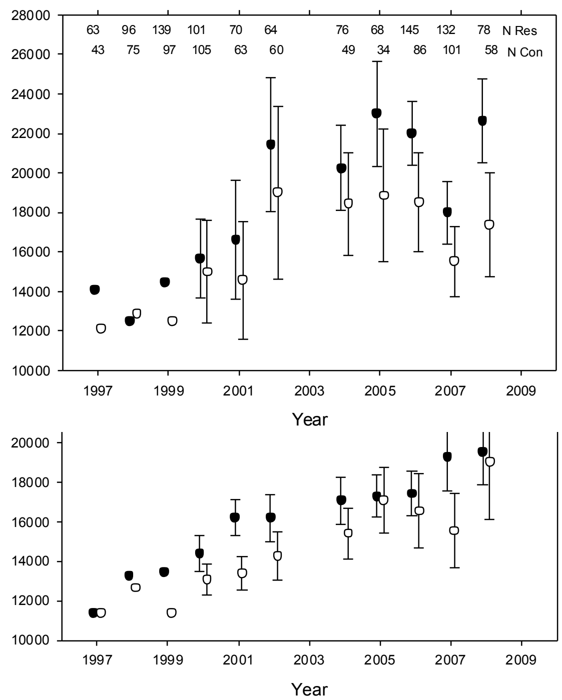

Figure 5. Egg production per female (*y*-axis) in closed areas (filled circles) and adjacent areas (open circles) at Round Island, Bonavista Bay (top graph), and Duck Island, Bonavista Bay (bottom graph). <u>Graphs reproduced from Collins 2010.</u>

In an unpublished study Kate Wilke and Jennifer Janes found inconsistent results among locations; two closed areas had larger females and males within the closure (Gander Bay and Summerford), two had larger males only (Round Island and Duck Island) and two had no significant size differences (Shoal Point and Trout River) (Fig. 6).

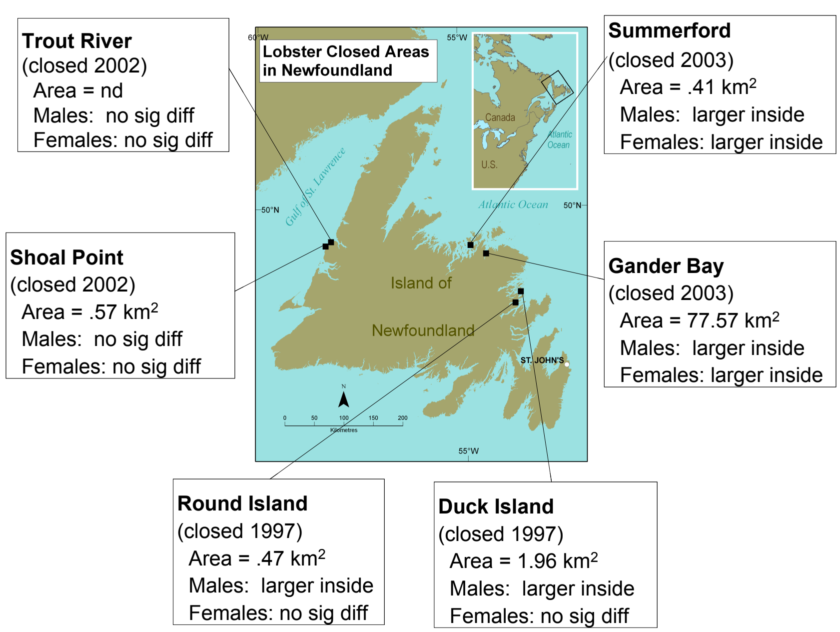

Figure 6. Effects of closed areas on female and male lobster sizes for 6 closures in Newfoundland.

Value of result: Closing an area does not guarantee an increase in lobster size. Factors such as location and size of closed area, suitable habitat (affecting survival and growth), and lobster movement (affecting recruitment) may be responsible for inconsistent effects among locations.

Closing an area to fishing increases reproductive value by reducing mortality and so increasing size and egg production. The calculated increase in reproductive value, 65%, was greater than the other conservation measures; however, this increase is restricted to small areas, in contrast to v-notching and slot fishing, which apply to entire lobster fishing areas.

Goal 4: Large-scale effects of closed areas

The fourth goal of this project was to determine the spatial scale at which closed areas (MPAs) increase reproductive value of lobster populations. Closed areas were found to significantly increase reproductive value within the closure. Does this increase reproductive value at a larger scale? The large-scale effect of MPAs on reproductive value (RV) was calculated using the following equation (Xu and Schneider, in press):

Eq. [1] RV_{total} (MPA)/RV_{total} (no MPA) = 1 + (1.65 x 1.2 – 1) x %MPA

where % MPA = Area of MPA/(Area of MPA + Surrounding Area)

For example, two closed areas, Round Island and Duck Island, are present in Bonavista Bay.

To calculate the expected increase in reproductive value at the scale of the MPA and area adjacent to the MPA we take the ratio of the MPA area to the surrounding area and then put this into Eq. [1]

For the area adjacent to the MPAs, of similar extent as the MPA

%MPA = [(Round + Duck)/(Round + Duck + Adjacent) x 100%
%MPA = [2.5 km^2/(2.5 km^2 + 2.5 km^2)] x 100%
%MPA = 50%

RV_{total} (MPA)/RV_{total} (no MPA) = 1 + (1.65 x 1.2 – 1) 50% = 149

The small protected areas in Eastport will increase the reproductive value in the area immediately adjacent to the MPAs by a factor of approximately 149.

To calculate the expected increase in reproductive value at the larger scale of Bonavista Bay we take the ratio of the MPA area to the surrounding area and then put this into Eq. [1]

For Bonavista Bay:

$$\%MPA = [(\text{Round Island} + \text{Duck Island})/\text{Bonavista Bay}] \times 100\%$$
$$\%MPA = [2.5\ km^2/(2.5\ km^2 + 3600\ km^2)] \times 100\%$$
$$\%MPA = 0.07\%$$

$$RV_{total}\ (MPA)/RV_{total}\ (\text{no MPA}) = 1 + (1.65 \times 1.2 - 1)\ 0.07\% = 1.07$$

The small protected areas in Eastport will increase the reproductive value in the entire bay area by a factor of approximately 1.07.

Protected areas are expected to have a substantial effect on reproductive value in adjacent areas of similar size, but little expected effect at the scale of a lobster fishing area or bay.

Value of result: Similar calculations can be made for any of the effects reported by Collins (2010) for the Eastport MPA, including greater size, greater numbers per unit area and greater egg production. At a small scale, some (though not all) MPAs can substantially increase local egg production. At a large scale, MPAs are more important as refuges against recruitment failure in a fishery where most individuals reproduce only once. MPAs are likely to be of value to those fishing immediately adjacent to the MPA.

Goal 5: Promoting Stewardship: Following up on Fishermen's Questions

The fifth goal of this study was to promote stewardship by building a cooperative, community-based research approach where resource users participate in the science, not only by gathering data, but also by shaping the research questions. There were multiple interactions with the harvesters who voiced their concerns about how scientific research is conducted as well as questions about how effective initiatives such as releasing large female lobsters and voluntary v-notching actually are. Because catch rates vary considerably, and are the result of many factors, harvesters were uncertain about the effectiveness of practices such as v-notching, MPAs, and a slot fishery. This community based approach allowed a dialogue between the community and researchers that resulted in several new studies or literature reviews that would not have been otherwise carried out.

Q. Why do scientists get licenses to remove eggs from lobsters while we have to release egg bearing lobsters back into the water?

Traditional techniques to estimate the number of eggs a female is carrying rely on removing all of the eggs from a lobster. This practice directly acts contrary to the regulated release of berried females by harvesters. To resolve this duality in practice, a non-invasive sampling technique was created to estimate egg numbers on lobsters without removing all of the eggs (Currie et al. 2010).

Value of result: Stock assessments on egg production can be done while still respecting the conservation measures to protect egg-bearing females.

Q. We keep catching these females too big to keep, but with no eggs; do large females reproduce less frequently than smaller females?

Kate Wilke assembled data from 2006 through 2011 on over 50,000 lobsters from LFA14A and LFA14B, and another 6000 from LFA 12, 13A, and 13B. The percent with eggs increased slightly with increasing size above a carapace length of 82.5 mm. Frequent catches of large females above the legal limit in a slot fishery may be due to repeated catches of the same individual. This explanation is readily tested by marking large females that are released in a slot fishery.

Q. My catches haven't increased. Does v-notching actually work?

When we run the numbers, we find that v-notching increases egg production substantially, by allowing some females to reproduce repeatedly. V-notched lobsters accounted for 6.8% of the catch but 42% of the estimated egg production (see results in Goal 3, above).

Conclusions

V-notching and slot fishing (protecting sizes less than 82.5 mm and greater than 127 mm) increases current egg production and reproductive value (current and future egg production) by a substantial margin. Closed areas increased lobster number, sizes, and egg production compared with surrounding areas. The local effects were substantial at Eastport; similar effects were found at some but not all closed areas. All three measures are shown to increase current and future egg production individually; however, a combination of v-notching, slot fishing, and closures would be more effective than any one measure for sustainability. Reproductive value takes information on egg production, growth rates, and mortality and combines it into one value that effectively characterizes the individual worth of a lobster to its population and can be used to assess conservation measures. Reproductive value relative to dollar value needs to be considered for sustainable fisheries. It is useful for communicating with the fishing industry the trade-off between the value of a lobster in sustaining future stock and its current economic value.

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