



Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Correspondence

A Response to the letter to the editor 'Lack of interaction between finfish aquaculture and lobster catches in coastal Nova Scotia'


The purpose of our study was to examine lobster catch data in the vicinity of an established finfish farm over a seven year period (Loucks et al., 2014). The study encompassed periods of Rainbow trout (*Oncorhynchus mykiss*) and Atlantic salmon (*Salmo salar*) production (2007–2013) in open marine net pens. Stocking levels at the fish farm have typically been 200,000 Atlantic salmon or 400,000 Rainbow trout. The water depth is 10–12 m (Chart datum from Nova Scotia Fisheries and Aquaculture Environmental Monitoring Program) with a tidal range of 2 m (Gregory et al., 1993). This shallow depth is a factor in the limited flushing capacity of the bay.

In their critique of our study, Grant et al. conclude that we provide no evidence of interaction between finfish aquaculture and lobster catches. We examined their evidence and offer the following response.

1. Experiment'al Design

Grant et al suggest that the uneven region size of the spatial design introduces a potential source of bias into comparisons of catch per unit effort (CPUE) among regions.

While the spatial area of the five lobster fishing regions in our study are unequal, it cannot be assumed that all areas within these regions have suitable lobster habitat. Lobsters distribution is widely known to be strongly associated with coarse boulders-type habitat rather than on habitats with sediments of smaller grain size (Tremblay et al., 2009). According to fishermen participating in our study, not all of the seabed in each region is productive lobster fishing area and subregions of lobster habitat (e.g. around rocky shorelines and ledges) were relatively balanced among the regions.

2. Regional distribution of effort

Grant et al. suggest that our study failed to provide the regional distribution of trapping effort and, therefore, it was impossible to evaluate this potential source of bias.

In our study regional distribution of trapping effort was embedded in CPUE which provided normalization of effort in each region. Fishermen optimize their catch - when CPUE is low in a particular region, trapping effort will be limited as traps are not left for long in areas where catches are low or negligible. Each trap haul represents costs in time, fuel and bait, otherwise costs may exceed revenue. Spatial distribution of effort over the two weeks of survey in each year (2007–2013) varied with the pattern of lobster catches. We acknowledge that there is a bias toward elevated CPUE because the fishermen follow the lobsters to

optimize their catch - a consistent feature of the fishing practice, but not a driver of the (CPUE) trends.

The study period - the last two weeks of May - was chosen because this period represents a time when higher numbers of lobsters historically migrate into the bay to spawn and moult. Female ovigerous lobster were released. This time period also provides an upward bias on lobster catches.

Grant et al. cast doubt on the influence of aquaculture on lobster fishing in Region 2 by suggesting that: other adjacent fishing regions have a similar linear distance from the fish farm; lobsters were being trapped before they reached Region 2; a fish plant located in Region 2 provided a 'huge' source of organic input that confounded the inputs from the fish farm; and, marine traffic around the fish plant reduced the catchability of lobster.

Simple linear distance from the fish farm does not take into account the fine scale, bathymetric details of sills and basins and tidal circulation patterns within the fishing Regions. Historically, before the fish farm was established, all regions of the bay contained productive lobster fishing areas, particularly Region 2 during the last two weeks of May. The bay and particularly the inner bay was also the preferred area to fish because of short distance from wharves, less cost of fuel, fewer fishing days lost to poor weather, less gear loss and less safety risk.

The fish plant operated at peak capacity until the collapse of the ground fishery in the late 1980's. Subsequently, it operated at a very reduced level. During the period of our study (2007–2013), there was little or no processing at the fish plant and, therefore, little or no source of organic effluent from the fish plant. The plant closed in 2014.

Finally, there is no reason to infer that marine traffic around the fish plant reduced catchability in Region 2 since the greatest vessel traffic near the fish plant occurs in August to October during the herring fishery season which does not coincide with the lobster season.

3. Statistical analysis

Grant et al. state that lobster traps were not geo-located, the mode of designating catch per spatial sector was not reported and it was not known whether zero (empty trap hauls) were included in these data.

The type of study design suggested by Grant et al. is not practical in this case. GPS coordinates for each trap location were not considered feasible as boats typically haul 250 traps per day, while re-locating some traps. Each day, the total number of trap hauls, total pounds of market lobsters caught and total number of ovigerous lobsters caught and returned to the sea in each region were recorded by each boat in a manner similar to the log reports provided by each boat in much larger Grid areas of Lobster Fishing Area 33 to the Department of Fisheries and Oceans Canada. Zeros were included when total pounds of market lobsters or numbers of ovigerous females per day in a particular region were zero.

This data- rich study was a voluntary community survey conducted confidentially among the fishermen with only the aggregated results posted. A frequent criticism made of fisher-collected sampling

DOI's of original article: <http://dx.doi.org/0.1016/j.marpolbul.2014.08.035>, <http://dx.doi.org/10.1016/j.marpolbul.2016.06.043>

programs is that they can be biased. New Zealand studies of fisher-collected sampling programs found no evidence of bias and concluded that their high-quality data could be used in quantitative fisheries stock assessment (Starr and Vignaux, 1997; Starr, 2010).

Grant et al. state that no information was provided about the variation in catch for mean CPUE per annual sampling period to allow assessment of significance of temporal trends with time.

CPUE's for each region for the same 2-week period for each year were calculated using the total number of pounds of market lobsters caught divided by the total number of trap hauls by all boats in a particular region; similarly the total number of ovigerous female lobsters per 1000 trap hauls by all boats in a particular region. These calculations produce two time series annually across the five regions - CPUE values for market lobsters and numbers per 1000 hauls for ovigerous female lobsters. These are both aggregate values for each region in each year. This CPUE data treatment is used by DFO for lobster stock status updates (DFO 2015). The statistical treatment points raised by Grant et al. which relate to variance in catch do not apply to this study.

Grant et al. suggest that the regression analysis was unusual, the core results cannot be assessed as real, and the sample size for the statistical analysis is insufficient ($n = 3$).

The independent variable formulation in our study - in this case, 0 (fallow) or 1 (farm feeding) - can be used to introduce a threshold forcing variable which indicates the environmental regimes (Cianelli et al., 2008). We measured the strength of the association between lobster CPUE's (ovigerous and market) and the fish farm's feed/fallow period in each fishing region, performing a t-test ($t = r[(n-2)/(1-r^2)]^{1/2}$) on the correlation, where $n = 7$, the number of replicate years of sampling, not 3, as suggested by Grant et al.

4. Environmental influences

Grant et al. suggests that our study neglected the potential effect of other obvious environmental and fishery variables on lobster catches such as moulting, weather conditions and water temperature, one of the major drivers of lobster CPUE.

The lobster season in Port Mouton Bay ends in May before the lobster moulting period begins. Some fishing days during the study period were lost due to poor weather conditions, i.e. high winds. No traps were hauled on those days.

Our study acknowledged the influence of temperature on lobster catches and provided bottom temperature records from a temperature data logger during the study period as opposed to surface temperature records. Bottom temperatures relate directly to lobster habitat on the sea bed and lobsters respond to ambient temperatures. It was also pointed out that if temperature was the only factor in the study, catch rates should have been high across all regions of the bay in 2010 when bottom temperatures were highest over the seven-year study period. Catch rates did increase in 2010 in all regions except Region 2 which included the fish farm. Lower temperatures, therefore, are an unlikely explanation for the low catch rates in Region 2 in the vicinity of the fish farm.

Our study design accounts for the migratory movement of lobsters as water temperatures increase near the end of the lobster fishing season when lobsters move inshore to shallow (and warmer) water in coastal areas for the annual spawning and moulting cycle. If there is no habitat disturbance, it is this annual temperature signal which is the predominant factor influencing the movement of lobster into inshore coastal areas (Aiken and Waddy, 1986).

In studies of fish abundance and environmental forcing, changes in distribution can often be the result of smaller scale variability, like those associated with the physical and biological feature of the species habitat, that are not clearly identifiable through large-scale indices. There are few if any studies that look at local or small scale disturbances (e.g., habitat or water quality) and impacts on American lobster abundance, distribution, behaviour or catch. Our study focused on factors

affecting lobster catches at a small spatial scale (e.g., habitat disturbances potentially caused by a fish farm) rather than larger-scale oceanographic factors and their impact on lobster landings aggregated over larger spatial scales as suggested by Grant et al.

Grant et al. suggests that a mechanism of far-field interaction of lobsters with the fish farm cannot be formulated because sulphidic compounds released from sediments under net pens cannot travel long distances and nitrogenous farm wastes such as ammonia are quickly diluted to background levels.

Open net finfish aquaculture operations can produce odours and change benthic habitat and water quality. These changes can include the production of hydrogen sulphide and anoxic conditions from decomposing fecal particles, and macro- and microalgal blooms caused by excess nutrient loading. The magnitude of the changes depends on many factors including: the size of farm operation (number of net pens per operation); density of fish per net pen; duration of farm operation on a particular site; physical and oceanographic conditions; natural biota of the region; and the assimilative capacity of the environment.

Strain and Hargrave (2005) reported that total dissolved nitrogen released from farms in an inlet in southwestern New Brunswick was a significant contributor to nutrient loading compared to other nutrient inputs and natural processes. Due to the nitrogen limiting factor in seawater in this region, excess nutrient loading can be readily transformed into nutrient sinks such as mobile algae mats (Robinson et al., 2005). Fishermen in our study reported lobster traps covered with odorous, nuisance 'slime' algae (a response to nutrient loading) at distances of kilometers when the fish farm was in operation and restricted to a zone nearer the fish farm site during the period of fallow.

Our study refers to the extra-ordinary olfactory sense of lobster which Park et al. (2014) describe as a mechanism of olfactory neurons that constantly discharge small bursts of electrical pulses, much like radar which lobsters use in their search for food or to avoid danger. Hydrodynamics are also reported to play a role in chemoreception in crustaceans such as lobster - more turbulence due to bottom roughness in boulder environments providing animals with more sensitivity to discrete rapid, odor plumes. (Weissburg and Zimmer-Faust, 1993; Tremblay and Smith, 2001).

Grant et al. (2016) refer to a study by Brager et al. (2014) showing that an enhanced particulate plume from fish farms cannot be detected beyond farm boundaries.

We note that the Brager et al. (2014) study was conducted in areas of the Canadian Pacific and the Bay of Fundy in eastern Canada where oceanographic conditions are not matched in Port Mouton Bay. Water depth, current speed, stocking density and other husbandry practices that are known to affect the fate and impact of waste from salmon farms may be sufficiently different to make comparisons to Port Mouton Bay inappropriate.

Despite more than three decades of aquaculture activity in Canada, very few scientific studies have been done on the far-field/cumulative effects of open pen fish farms on traditional fisheries. In 1990, a diving survey by federal government scientists examined fishermen's concern over the potential effects of a recently expanded salmon farm on lobster habitat in Flagg Cove, New Brunswick (Canada). Comparison of data from surveys in 1982, 1983 and 1989 in Flagg Cove, led to documentation of lobster displacement in 1990 (Lawton and Robichaud, 1991). In the past five years, there has been a greater interest in documenting the observations of local fishermen, for example, Wiber et al. (2012) which documented the observations of fishermen in New Brunswick (Canada) and their interactions with open net pen fish farms. Our study continues annually.

5. Conclusion

We agree with Grant et al. that open net pen fish farming in coastal waters is a contentious activity. More studies involving fishermen are

needed. In the meantime, we conclude that the evidence Grant et al. have provided is insufficient to invalidate the findings of our study.

References

- Aiken, D.E., Waddy, S.L., 1986. Environmental influence on recruitment of the American lobster, *Homarus americanus*: a perspective. *Can. J. Fish. Aquat. Sci.* 43, 2258–2270.
- Cianelli, L., Fauchald, P., Chan, K.S., Agostini, V.N., Dingsør, G.E., 2008. Spatial fisheries ecology: Recent progress and future prospects. *J. Mar. Syst.* 71, 223–236.
- Grant, J., Filgueira, R., Barrell, J., 2016. Lack of interaction between finfish aquaculture and lobster catch in coastal Nova Scotia. <http://dx.doi.org/10.1016/j.marpolbul.2016.06.043>.
- Gregory, D., Petrie, B., Jordan, F., Langille, P., 1993. Oceanographic, Geographic and Hydrological Parameters of Scotia-Fundy and Southern Gulf of St. Lawrence Inlets. *Can. Tech. Rep. Hydrogr. Ocean Sci.* 143 (viii + 248 pp.).
- Lawton, P., Robichaud, D., 1991. Shallow water spawning and molting areas of American Lobsters, *Homarus Americanus*, off Grand Manan, Bay of Fundy, Canada. *J. Shellfish Res.* 10, 286.
- Loucks, R.H., Smith, R.E., Fisher, E.B., 2014. Interactions between finfish aquaculture and lobster catches in a sheltered bay. *Mar. Pollut. Bull.* 88, 255–259.
- Park, I.M., Bobkov, Y.V., Ache, B.W., Principe, J.C., 2014. Intermittency coding in the primary olfactory system: a neural substrate for olfactory scene analysis. *J. Neurosci.* 34 (3), 941–952.
- Robinson, S.M.C., Auffrey, L.M., Barbeau, M.A., 2005. Far-field impacts of eutrophication in the inter-tidal zone in the Bay of Fundy, New Brunswick, Canada with emphasis on the soft-shelled clam *Mya arenaria*. In: Hargrave, B.T. (Ed.), *Environmental Effects in Marine Fin Fish Aquaculture Handbook of Environmental Chemistry vol. 5M*. Springer, Berlin, Germany, pp. 253–274.
- Starr, P., 2010. Fisher-Collected Sampling Data: Lessons from the New Zealand Experience. *Mar. Coast. Fish.* 2 (1), 47–59. <http://dx.doi.org/10.1577/C08-030.1>.
- Starr, P.J., Vignaux, M., 1997. Comparison of data from voluntary logbook and research catch-sampling programmes in the New Zealand lobster fishery. *Mar. Freshw. Res.* 48, 1075–1080.
- Strain, P., Hargrave, B., 2005. Salmon aquaculture, nutrient fluxes and ecosystem processes in southwestern New Brunswick. In: Hargrave, B.T. (Ed.), *Environmental effects of marine finfish aquaculture Handbook of environmental chemistry vol. 5M*. Springer, Berlin, Germany, pp. 29–57.
- Tremblay, M.J., Smith, S.J., 2001. Lobster (*Homarus americanus*) catchability in different habitats in early spring or late fall. *Mar. Freshw. Res.* 52, 1321–1331.
- Tremblay, M.J., Smith, S.J., Todd, B.J., Clement, P.M., McKeown, D.L., 2009. Associations of lobsters (*Homarus americanus*) off southwestern Nova Scotia with bottom type from images and geophysical maps. *ICES J. Mar. Sci.* 66, 2060–2067.
- Weissburg, M.J., Zimmer-Faust, R.K., 1993. Life and Death in Moving Fluids: Hydrodynamic Effects on Chemosensory-Mediated Predation. *Ecology* 74 (5), 1428–1443.
- Wiber, M., Wilson, L., Young, S., 2012. Impact of aquaculture on commercial fisheries: Fishermen's local ecological knowledge. *Hum. Ecol.* 40 (1), 29–40.

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12 June 2016