



Comparing the Effectiveness of Traditional and Alternative Baits in Prince Edward Island, Canada Lobster Fishery

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The American lobster (*Homarus americanus*) fishery is an economically important commercial activity in Prince Edward Island (PEI), Canada. This fishery requires substantial amounts of bait, resulting in an emerging conservation challenge. To address this issue, an alternative lobster bait, manufactured using fresh and process pelagic fish, and dehydrated fish, corresponding to 75% less fresh pelagic fish than traditional bait has been developed by Bait Masters Inc. The performance of the alternative bait compared to that of the traditional bait was evaluated in a field study. This field trial was conducted in eight lobster fishing bays around PEI, during the 2019 lobster fishing seasons. Bait effectiveness was assessed based on catch-per-unit-effort (total lobsters and number of legal-sized lobsters caught per trap), and the ability to produce a catch. An average of five lobsters per trap were caught for both alternative and traditional baits. The results showed that both lobster bait types performed equally well in all PEI lobster fishing areas studied. This indicates that the alternative bait is a viable replacement for traditional bait, allowing the lobster fishery industry to address the bait-species shortage and ongoing conservation challenge.

Keywords: alternative bait, lobster, forage fish, fishery, sustainability, bait

INTRODUCTION

American lobster (*Homarus americanus*) is an iconic Canadian species and the country's most valuable seafood export, having generated a total of \$2.6 million CAD in international exports in 2019 (Fisheries and Oceans Canada, 2020a). Lobster fishery is an economically important commercial activity for Prince Edward Island (PEI), which accounts for approximately 17.5% (17,014 metric tonnes) of the annual Canadian lobster landings (Fisheries and Oceans Canada, 2018). PEI has two lobster fishing seasons. The spring lobster fishing season runs from May to June and provides about 80% of the annual landing. The second season runs in late summer, from mid-August to mid-October, but is often referred to as fall lobster fishing season (Province of PEI, 2013). Conservation practices, including the implementation of a minimum legal harvesting size, fishing seasons, escape mechanisms in the traps (for undersized lobsters), the number of fishing licenses and limits on the number of traps laid have contributed to the stable and successful development of this fishery (Fisheries and Oceans Canada, 2013).

Lobsters are caught in baited traps placed on the bottom of the sea. Commercial lobster fishing requires a significant amount of bait that traditionally relies heavily on forage fish such as herring (*Clupea harengus harengus*) or mackerel (*Scomber scombrus*) (Harnish and Willison, 2009; Dellinger et al., 2016). This practice is resource consuming for fishermen and depletes bait species stocks. Consequently, the overfishing of forage fish for crustacean bait and to meet other competing demands, such as human consumption, has led to the emergence of conservation challenges for these fish species. As traditional baits become scarcer, efforts have been made to produce more sustainable alternative baits, to alleviate some of the pressure that is currently placed on bait species used by the industry (Chanes-Miranda and Viana, 2000; Dellinger et al., 2016; Masilan and Neethiselvan, 2018; Araya-Schmidt et al., 2019).

There have been studies quantifying bait used per catch (Harnish and Willison, 2009), and evaluating economic viability of using alternative baits, e.g., green crab (St-Hilaire et al., 2016) and cunner (Hewitt, 2018) in Atlantic Canada's lobster fisheries. However, there is still much to learn about the effectiveness and sustainability of alternative baits in lobster fishery and the number of studies on this topic is very limited.

A more sustainable and environmentally friendly bait has been developed by Bait Masters Inc., to replace the traditional bait used in PEI's lobster fishery. This alternative bait is made from a mixture of fresh and processed pelagic fish, contained in an organic biodegradable casing. The amount of fresh pelagic fish required in the alternative bait corresponds to one-quarter of that used in traditional bait.

In the present work, we evaluated the effectiveness, in terms of catch-per-unit-effort (CPUE; defined as total lobsters and legal-sized lobsters caught per trap) and catchability, of an alternative bait compared to the traditional bait, using data collected from a field trial carried out in PEI during the spring and fall of 2019 lobster fishing seasons.

MATERIALS AND METHODS

Alternative Bait Composition

Alternative bait used in this study is made from a mixture of 25% fresh and 50% processed pelagic fish (mackerel and/or herring), 10% dehydrated fish, and 15% oil and binder, contained in an organic biodegradable casing. This plant-based case is mainly made from banana peels. The bait disintegration time (i.e., period of time from when the bait is first put in water to its complete disintegration) has been observed to be, on average, 5 days in seawater, while the traditional bait lasts for one to 2 days (M. Prevost, Personal communication, September 23, 2020).

Study Area

The Southern Gulf of St. Lawrence region, PEI, consists of five lobster fishing areas (LFAs): 23, 24, 25, 26A, and 26B (Figure 1), based on the definition by Fisheries and Oceans Canada (DFO) (Fisheries and Oceans Canada, 2014a). LFAs 24 and 26A have spring lobster fishing season, which runs from May until the end of June, while LFA 25 is fished in the fall lobster fishing season

and is active from mid-August until mid-October (Fisheries and Oceans Canada, 2014b).

Study Design and Data Collection

Field trials were carried out in eight bays from three LFAs around PEI (i.e., 24, 25, and 26A), representing both northern and southern coasts of the province; the latter includes the Northumberland Strait (Figure 1). To account for variations in fishing experience, weather conditions, and day-to-day variations, lobster traps were deployed from 12 commercial fishing boats over six consecutive fishing days, during the spring and fall of 2019 PEI lobster fishing seasons. A single boat was used in each bay, with the exception of Nine Mile Creek bay, in which five boats were used. For each boat, six "sites" were randomly selected based on feasibility to deploy lobster traps (Figure 1). Six lobster traps were tied in a longline to form a "trap set." Two trap sets, each using the same type of bait (traditional or alternative baits), were deployed per site, 30 – 90 meters apart, to ensure other conditions (such as lobster abundance and hydrodynamic conditions, etc.) associated with CPUE and catchability, were similar for both trap sets. At the sites where it was not feasible to place a pair of trap sets, a single trap set with the same number of traps of each bait type (three to six, depending on the site) was used and the bait order in that trap set was alternated between traditional and alternative baits. An equal amount of bait was used in all lobster traps from the same pair of trap sets to account for effect of bait quantity on CPUE and catchability.

Lobster traps were set daily (from Monday to Saturday) in each "site." The traps were retrieved the following day, except for those set on Saturdays (which were retrieved 2 days later) or whenever the weather was not permitting. Upon the trap retrieval, lobsters were removed from the trap, measured and counted, and those that met legally harvest requirements were kept, while the rest were released.

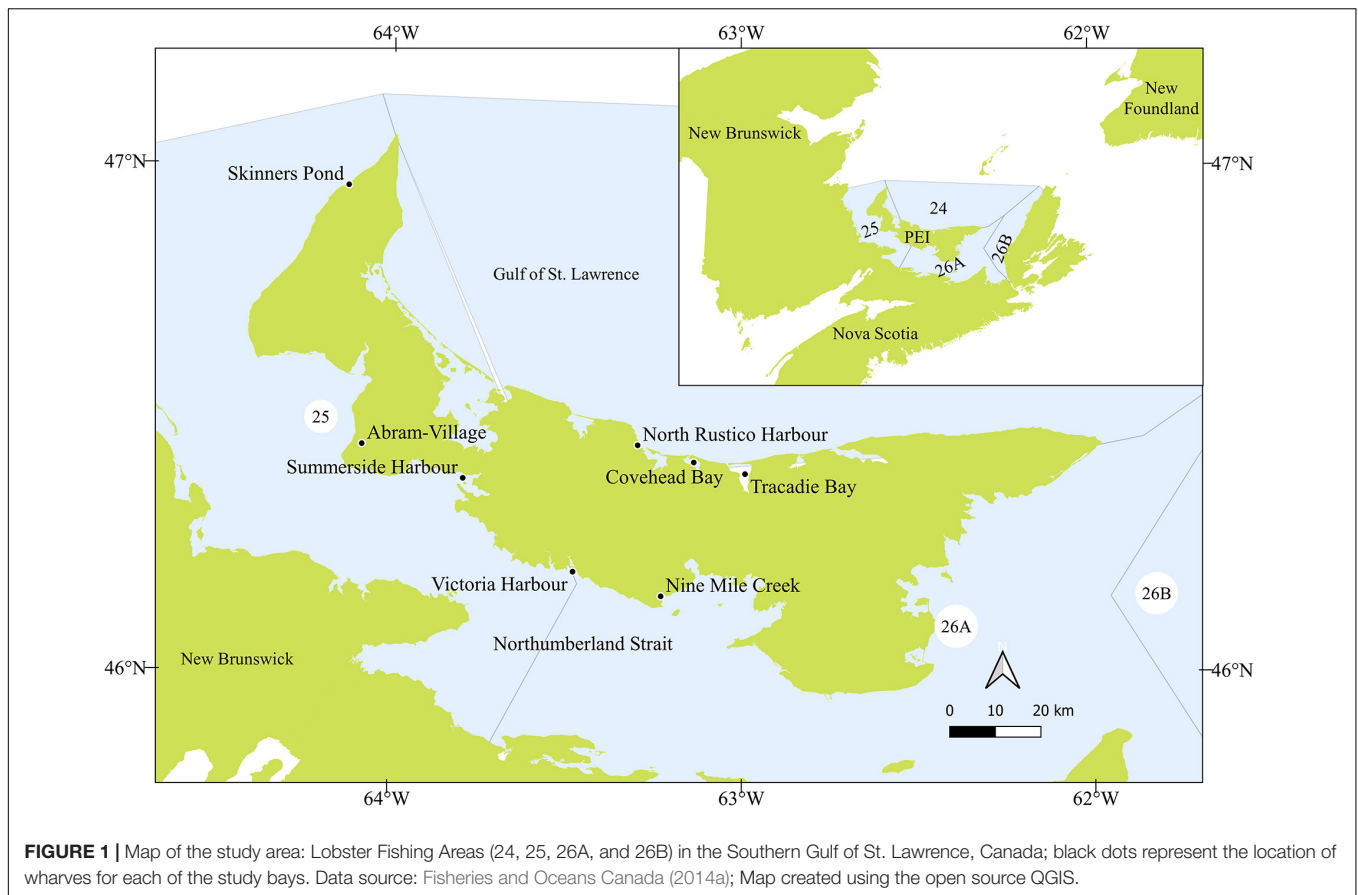
Data related to the total number of lobsters caught (categorized into legal-sized vs. restricted, and gender), type of bait, fishing boat, bay, trap number, date of trap set, date of catch, and water temperature were collected.

The restricted lobster refers to the lobster that did not meet the size restrictions, softshell lobsters, or egg-bearing females. The number of legal-sized lobsters caught was available and further broken down into number of male and female lobsters caught. The number of restricted lobsters caught was also recorded; however, information on gender of restricted lobsters was not recorded. The total lobsters caught per trap was calculated as the sum of the numbers of legal and restricted lobsters.

The duration of the trap in the water ("immersion time") refers to period of time from deploying to retrieving a trap. It was later categorized into the duration of one and more than 1 day. It was expected that the number of lobsters caught increased with the duration that the trap stayed in the water, and, therefore, this variable was accounted for in the multivariable analysis.

Data Analysis

Statistical analyses were performed using Stata (Release 16.1; StataCorp, 2019). A descriptive analysis was carried out to summarize the data. Mean and 95% confidence intervals,



adjusting for bay clustering effect, were computed for the count data for traditional and alternative baits.

Effectiveness of lobster bait was determined as (1) the catch-per-unit effort (CPUE), and (2) catchability. CPUE was measured by the total lobsters caught per trap, and the number of legal-sized lobsters caught per trap. Catchability was defined as the ability to produce a catch (i.e., at least one lobster caught). The effectiveness of the two bait types was evaluated using multivariable regression analysis, which was carried out separately for the spring and fall lobster fishing seasons.

Considering the overdispersion of data, we used negative binomial regression to evaluate the effect of each lobster bait on the numbers of total lobsters, and legal-sized lobsters caught per trap. The baits' ability to produce a catch (catchability) was assessed using logistic regression analysis. Bait type, bay, and immersion time were included in the analyses as fixed-effects. An interaction between bay and bait type was also included in the model to assess potential differences in the effect of bait on CPUE across different bays. These multivariable analyses also accounted for between-day variation of CPUE and catchability for each boat. We grouped boat and date of trap set into a new variable ("boat-date") and included it as a random-effect in the analyses. Water temperature data were missing from over half of the observations and therefore were not included in the analyses. Model assumptions were tested and residual diagnoses were performed (Dohoo et al., 2009). Akaike's information

criterion (AIC) was used to assess the fit of alternate models (Burnham, 2002).

RESULTS

Descriptive Analysis

Mean and 95% confidence interval, adjusting for the bay clustering effect, of the number of lobsters caught per trap, proportion of male and female lobsters, and proportion of non-empty traps by bait type are presented in **Table 1**. A total of 4,252 traps were set to capture lobsters on PEI waters during the spring and fall of 2019 lobster fishing seasons. The majority of traps (73%) were set in the spring and 28% in the fall lobster fishing season (**Supplementary Table S1**). The number of traps set were distributed equally between the traditional and alternative baits (**Table 1**). On average, a trap captured around five lobsters, with six percent of the catch being discarded due to size restrictions, shell condition, or reproductive status (i.e., bearing eggs). Approximately 70% of the legal-sized lobsters caught by each trap were male and 90% of the traps caught at least one lobster at the time of retrieval (**Table 1**). The average number of lobsters per trap caught by both alternative, and traditional baits were 3 (SD 2) for spring and 10 (SD 6) for fall lobster fishing seasons (data not shown).

TABLE 1 | Number of traps (n), mean and 95% confidence intervals adjusting for bay clustering for number of lobsters caught per trap and the proportions of legal-sized, and male lobsters per trap, and overall proportion of non-empty traps by bait type.

Variables	Traditional bait		Alternative bait	
	n	Mean (95% CI)	n	Mean (95% CI)
Legal-sized lobsters	2,127	5 (1, 8)	2,125	5 (1, 8)
Total lobsters	2,127	5 (2, 8)	2,125	5 (2, 8)
Male lobsters	1,855	3 (1, 4)	1,848	3 (1, 4)
Female lobsters	1,855	2 (0, 3)	1,848	2 (0, 4)
Proportion of legal-sized lobsters	1,924	0.94 (0.91, 0.98)	1,863	0.94 (0.89, 0.99)
Proportion of male lobsters	1,634	0.69 (0.50, 0.89)	1,569	0.67 (0.47, 0.88)
Proportion of non-empty traps	2,127	0.90 (0.78, 1.00)	2,125	0.88 (0.73, 1.00)

Multivariable Regression Model

Results from the multivariable regression model, evaluating the effectiveness of lobster baits, while accounting for immersion time and boat-date are presented in **Table 2**. The interaction effect between bait and bay are presented in **Figure 2**. Since the outputs for legal-sized lobsters and the total lobsters caught per trap were similar, only the results for the latter are presented. The total number of lobsters caught per trap using the alternative bait was not significantly different from that obtained using the traditional bait in all bays (**Figure 2**). Additionally, the probability of producing a catch was not significantly different between the two bait types in any of the studied bays (**Supplementary Figure S1**).

DISCUSSION

This study represents the first field trial to evaluate the performance of an alternative bait in the commercial capture of lobsters in PEI. Our results indicate that the ability to produce a catch (catchability) of traditional and alternative baits was not

different in all studied bays. The two bait types also yielded a similar CPUE in these bays.

Although our study design controlled for the effect of bait quantity and the analysis adjusted for immersion time and spatial variation, we could not account for bait loss due to other factors such as predation and disintegration. The amount of bait used per trap has been shown to be correlated with the number of lobsters caught in Maine, the United States, and Nova Scotia, Canada (Saila et al., 2002; Harnish and Willison, 2009). However, it is challenging to quantify the amount of bait loss to other factors in a field setting. For this reason, this was not accounted for in the analyses but could potentially have affected the number of lobsters caught.

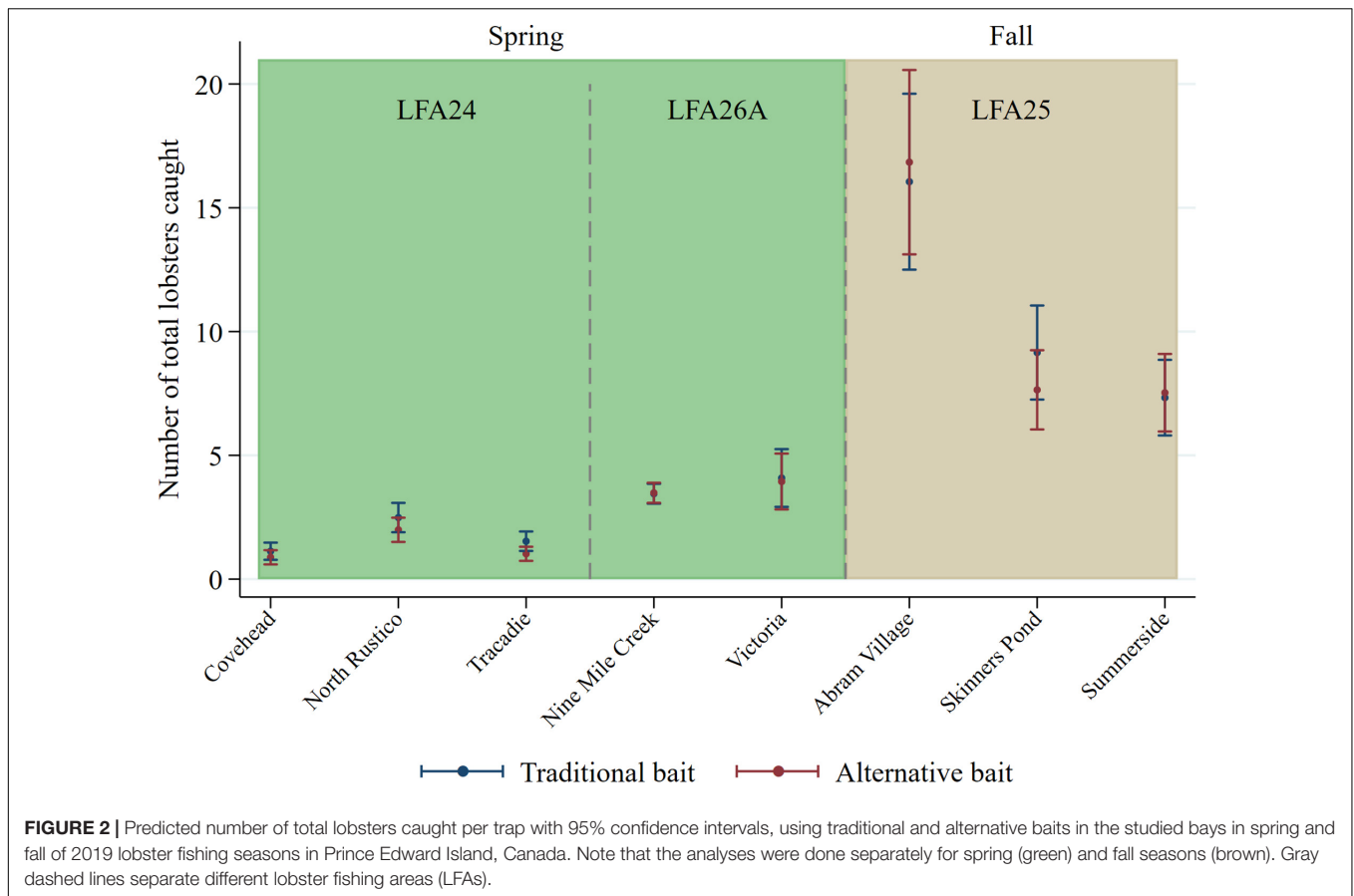
Under field conditions, disintegration time of this alternative bait has been observed to be longer than that of the traditional bait, depending on hydrodynamic conditions (M. Prevost and W. MacPhee, Personal communication, July 27, 2020); however, this observation has not been statistically tested.

The number of lobsters caught was higher during the fall than in the spring lobster fishing season. This same pattern was also observed in Nova Scotia by Harnish and Willison (2009).

TABLE 2 | Coefficients (β), 95% confidence intervals, and p -values for the effect of bait type, after accounting for other factors, on the number of lobsters caught per trap using negative binomial multivariable regression analyses for spring and fall of 2019 lobster fishing seasons.

Variable	Spring			Fall		
	β	95% CI	p -value	β	95% CI	p -value
Bait						
Traditional	(Reference)					
Alternative	-0.25	[-0.47, -0.03]	0.03	0.05	[-0.02, 0.11]	0.16
Bays	-		< 0.01	-		< 0.01
Bay \times Bait ^a	-		< 0.01	-		< 0.01
Immersion time^b						
1 day	(Reference)					
> 1 day	0.14	[0.01, 0.28]	0.04	0.20	[-0.01, 0.41]	0.06
Constant	0.06	[-0.15, 0.27]	0.56	2.71	[2.54, 2.88]	< 0.01
Ln(Alpha)	-3.36	[-3.89, -2.82]		-3.25	[-3.53, -2.97]	
Random effect						
Boat-date: variance (SE)		0.02 (0.01)		-		

Note that the analyses were done separately for spring and fall seasons. ^a Details on interaction term (Bay \times Bait) are presented in **Figure 2**. ^b refers to period of time from deploying to retrieving a trap.



However, this temporal variation in the number of lobsters caught may be a result of seasonal geographical differences, given that the fishing activity in the fall lobster fishing season occurs only in LFA 25. The water depth in the Northumberland Strait tends to be shallower than that of other areas around PEI (den Heyer et al., 2009; Obert and Brown, 2011). Lobsters tend to migrate from shallow waters to the north of PEI before and during winter to avoid ice at the sea bottom. They later return to warmer waters in the Northumberland Strait when the ice melts in the spring and do not move much from summer to winter (Comeau and Hanson, 2018). This may explain the larger number of lobsters caught in LFA 25 that occurred during the fall lobster fishing season.

While the two types of bait performed equally well, the alternative bait requires considerably less fresh forage fish in its composition. As the sustainability of traditional bait is at risk, DFO has imposed limitations on bait-species fishing quotas (Fisheries and Oceans Canada, 2020b,c). For this reason, the development of efficient alternative baits is of paramount importance to lobster fishery. In addition, it would help reduce financial burden, arising from labor and time dedicated to fishing bait-species, while creating job opportunities in parallel bait-producing industries. However, the lobster fishing community is traditionally reluctant to adopt alternative bait products out of fear of income loss due to ineffective baits.

New alternative baits should be properly evaluated in real field conditions, and their effectiveness supported by robust data to promote their widespread use. Similar studies in other LFAs would provide further evidence on the effectiveness of this or other alternative bait products. Results from such studies could provide assurance to the lobster fishing community and motivate them to use these baits, thus, allowing the industry to address the bait-species shortage and ongoing conservation challenge.

When conducting field trials to evaluate the effectiveness of lobster bait, potential spatial variation needs to be considered. The spatial difference in bait effectiveness may be linked to environmental factors, such as water temperature or bathymetry. The fact that lobsters rely on their olfactory system to detect and move toward food source (Derby and Atema, 1982; Devine and Atema, 1982; Moore et al., 1991; Lees et al., 2018), and that solubility of the solid substance (e.g., lobster bait) differs between colder and warmer temperature (Lu et al., 2020) may explain the spatial difference in the bait effectiveness.

The characteristics (i.e., composition and disintegration time) of the alternative bait studied help reduce the amount of fresh pelagic fish used and save bait-related costs. It is expected that fishermen would reduce their bait cost by 60–80%, saving approximately \$4.95–13.20 CAD for each kg of bait used (M. Prevost and W. MacPhee, Personal communication, September 22, 2020). However, no formal studies have been conducted to

assess the financial implications of type of bait used, therefore, a more in-depth analysis should be performed to evaluate the cost and benefits of alternative bait over traditional bait usage on lobster fishing.

CONCLUSION

Our study indicates that the alternative bait is a viable replacement for traditional bait. Further studies could be performed to evaluate the cost-effectiveness of the use of this alternative bait and quantify the reduction in forage fish use for bait production.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, upon reasonable request, without undue reservation.

AUTHOR CONTRIBUTIONS

KT designed the study and Bait Masters Inc. helped to conduct the field trial and data collection. TP, MD, and KT carried out the data management and statistical analyses. TP and MD wrote the first draft of the manuscript. All authors

contributed to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2020.589549/full#supplementary-material>

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