DEVELOPMENT OF A MONITORING FRAMEWORK FOR THE POTENTIAL ESTABLISHMENT OF A COMMERCIAL WHELK (*BUCCINUM UNDATUM*) FISHERY IN THE MARITIMES REGION (4Vs, 4W)

Photo Credit: Mark Wilcox

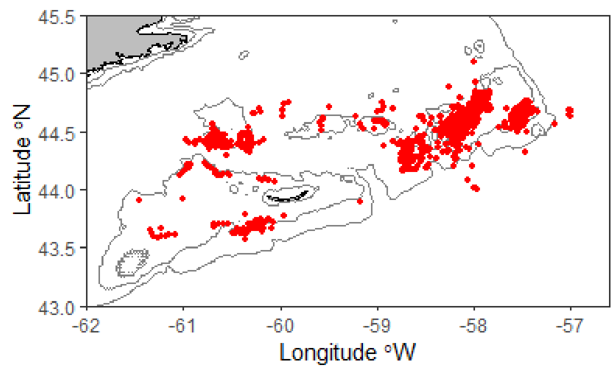

Figure 1. Distribution of whelk fishing throughout NAFO areas 4Vs and 4W between 2009 and 2019.

Context:

Waved whelk are a ubiquitous marine gastropod within the North Atlantic which, despite the wide range of the species, exhibit limited dispersal potential. This lack of dispersal contributes to spatial variability in shell morphology, size-at-sexual maturity, and size frequency of whelk populations, as well as, genetic differentiation over relatively small spatial scales. This makes whelk populations vulnerable to local depletion, or even extirpation, and slow to recover from their removal. Offshore whelk fishing in the Maritimes Region commenced within the Northwest Atlantic Fisheries Organization (NAFO) areas 4W and 4Vs in 2012. However, developing an assessment of stock status is hampered by limited information on natural abundance of whelks within fished areas and spatial extent and variation of whelk populations. Currently, there are no independent surveys that adequately sample whelk and, thus, information on these stocks is based solely on data collected by the exploratory license holders.

Fisheries and Oceans Canada (DFO) Fisheries Management has requested advice from DFO Science to assess current metrics gathered by the license holders and establish priority areas for research and analysis that will enable development of a stock assessment framework for offshore whelk. The information will be used by license holders to improve their research and fishing plans and, ultimately, to develop an assessment framework for the exploratory fishery that is consistent with DFO's Precautionary Approach. The review results provided in this Science Advisory Report include recommendations for industry research priorities and considerations for management of the resource.

This Science Advisory Report is from the February 19, 2020, Development of a Monitoring Framework for the establishment of a Commercial Whelk Fishery in the Maritimes Region (4Vs and 4W). Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- The Whelk Monitoring Document, provided by Fisheries and Oceans Canada (DFO) to the fishers, is adequate for recording the majority of metrics that will be used when developing an assessment framework, particularly the spatial extent of the resource, total landings, and Catch Per Unit Effort (CPUE).
- Moving forward, however, there is a need to ensure consistent reporting/recording of data on the Monitoring Document. It is particularly important to record effort and soak time for each string (a set of traps attached and deployed on a single line) to be able to accurately calculate CPUE.
- Measures of CPUE could provide an indicator of stock status; however, calculations did not account for soak time. This should be included when developing the CPUE indicator for an assessment framework. Abundance and biomass estimates would aid in the development of a future stock assessment model. A stratified dredge survey, such as that conducted in the Quebec Region, could provide a more accurate estimate of these parameters.
- Knowing that this species likely exhibits population structure over small spatial scales in 4Vs and 4W NAFO areas, and that whelk have a limited capacity for connectivity, a critical priority will be to continue to refine biologically appropriate management areas as information becomes available.
- More accurate differentiation between whelk species within the catch is necessary. Stimpson's Whelk appear to constitute a low proportion of the catch; however, this should be verified. The spatial variability of Stimpson's Whelk in the catch should also be determined.
- Determining temporal patterns of the reproductive cycle for whelk in this geographic region will not only provide a more appropriate temporal window when sampling for size- and age-at-maturity, but also identify periods when catches are likely to be minimized due to decreased feeding activities during reproduction.

BACKGROUND

Species Biology[1]

Buccinum undatum, the Waved Whelk, is a ubiquitous marine gastropod within the North Atlantic, distributed from the low water mark to depths of up to 600 m (Hansson 1998, Weetman et al. 2006, Włodarska-Kowalczuk 2007, Heude-Berthelin et al. 2011). Despite the wide range of this species, they exhibit limited dispersal potential as a result of internal fertilization, direct development of larvae within demersal egg capsules (i.e., lack of planktonic larvae), and limited adult movement (Pálsson et al. 2014, Lapointe and Sainte-Marie 1992, Hancock 1963, Himmelman and Hamel 1993). This lack of dispersal also contributes to the great deal of spatial variability observed in shell morphology, size-at-sexual maturity, and size frequency of whelk populations, as well as genetic differentiation over relatively small spatial scales (Weetman et al. 2006, Shelmerdine et al. 2007, Pálsson et al. 2014, McIntyre et al. 2015, Valentinsson et al. 1999). This makes whelk populations vulnerable to local depletion or even extirpation (Gendron 1991, de Jonge et al. 1993) and slow to recover from their removal.

[1] A more comprehensive review of the literature on whelk is available in the Research Document produced for this meeting.

The Fishery

Whelk fishing has been common throughout the range of the species. In the Maritimes Region, an offshore exploratory whelk fishery commenced within NAFO areas 4W and 4Vs in 2012, finding several areas that yielded high landings of whelk. Developing an assessment of stock status, however, is hampered by limited information with regards to natural abundance of whelks within fished areas, spatial extent, and variation of whelk populations. Currently, there are no independent surveys that adequately sample whelk and, thus, information on these stocks is based solely on data collected by the exploratory license holders.

ASSESSMENT

Catch Per Unit Effort, Landings, and Effort

Landings for the 4Vs subdivision have shown continual growth as fishery expansion into new areas yielded higher whelk catches and the Total Allowable Catch (TAC) increased in 2018 (Table 1). The highest landings to date in this subdivision were 665 t in 2018, with an average Catch Per Unit Effort (CPUE) of 14.88 kg per trap (with CPUE calculated as the sum of landings divided by the sum of effort). In 4W, following the identification of an area yielding higher quantities of whelk in 2017, landings increased to a high of 211 t in 2018, with an average CPUE of 3.56 kg per trap.

Table 1. Reported annual and average landings (tonnes), Catch Per Unit Effort (CPUE, kg/trap), effort in number (no.) of traps, and Total Allowable Catches (TAC, tonnes) for the offshore whelk fishery within 4Vs and 4W. Dashes (-) indicate no fishing in those years; n.a. indicates not applicable.

	4Vs				4W			
Year	Landings (tonnes)	CPUE (kg/trap)	Total Effort (no. of traps)	TAC (tonnes)	Landings (tonnes)	CPUE (kg/trap)	Total Effort (no. of traps)	TAC (tonnes)
2009	0.19	0.97	200	0.22	-	-	-	-
2011	60.46	9.35	6430	0.22	-	-	-	-
2012	0.23	0.38	585	350	0.34	0.49	697	700
2013	113.11	14.22	4820	350	0.01	0.06	225	700
2014	111.12	12.16	8000	350	0.18	0.24	750	700
2015	103.62	15.80	4399	350	1.14	2.28	500	700
2016	287.77	15.22	18905	350	0.12	0.10	1210	700
2017	352.43	17.15	20550	350	8.96	8.00	1120	700
2018	664.73	16.34	31777	700	211.23	3.97	36815	500
2019	549.16	13.81	23050	700	169.99	3.35	45250	500
Avg.	224.28	14.88	11872	n.a.	49.00	3.56	10821	n.a.

Values for CPUE were calculated based only on instances in DFO Maritimes Fishery Information System (MARFIS) when both effort and landings were recorded. Instances where landings are recorded with no effort values (24.3% and 11.7% across all years in 4Vs and 4W, respectively), and instances where there were no landings, were excluded. These missing data are due to a breakdown in the recording and reporting, and protocols should be reinforced to ensure effort is consistently included. Given that saturation does not appear to occur for whelk traps (Valentinsson et al. 1999), it would be advantageous to specify soak time (hours) by set on the monitoring document. Measures of CPUE could provide an indicator of stock status; however, calculations did not account for soak time. This should be included when developing the CPUE indicator for an assessment framework.

Biomass, Abundance, and Spatial Extent

Industry and academics have had difficulty obtaining an accurate density measure, which has limited the estimation of both biomass and abundance for this species. The use of landings as a surrogate for abundance provides only relative densities. The area of attraction, which influences the effective area of the trap (Miller 1975, Lapointe and Sainte-Marie 1992) is dependent on depth, current speed, and current direction (Himmelman 1988, Lapointe and Sainte-Marie 1992). These factors exhibit high spatial and temporal variability across fishing areas. Knowledge on the specific and situational effective area of any traps from which density is being estimated is necessary but logistically impractical to collect. Any conservative estimates based on assumptions of 100% depletion and a single effective area estimate (which we know to be highly variable) will produce considerably large confidence bounds. Efforts by researchers and industry to determine abundance through the use of a stock depletion model have been unsuccessful, as stocks did not indicate signs of depletion after multiple successive trips.

Efforts to describe spatial extent are ongoing and have recently identified new areas with higher quantities of whelk in both 4W and 4Vs. While fishing effort in both areas has provided data on the extent of whelk within areas of higher whelk density, further exploration would better delineate the boundaries of these areas. Accurate recording of data, including strings of traps where no catch was landed, is necessary to achieve this objective.

Bycatch

Bycatch appears to be negligible and consists mainly of hermit crab, Toad Crab, Rock Crab, and sculpin. More infrequently, sea stars, urchins, sand dollars, redfish, Snow Crab, and even whelk egg masses have been found in traps (or attached to traps/lines in the case of eggs). None of the poisonous Ten-Ridged Whelk, *Neptunea decemcostata*, or *Species at Risk Act*-listed species were encountered. Stimpsons Whelk, *Colus stimpsoni*, a sympatric species is also caught and landed. Their contribution to catch has been estimated to be less than 2% of whelk caught. Distinctions between the two species are not made at sea, but landings should be assessed periodically moving forward. This is of concern, as the depletion of *B. undatum* could result in a shift to a system dominated by the sympatric whelk species *C. stimpsoni,* which is already considered to be more dominant on parts of Banquereau (Kenchington and Glass 1998).

Monitoring documents provide space to record bycatch per trip; however, it could be beneficial to record such bycatch by string to incorporate spatial variability.

Life-History Traits

Research conducted by academic partners have examined life-history traits at 5 sites across 4Vs and 4W. Clear differences in size-at-maturity among sites were observed, with some differences occurring at very small spatial scales (15 km) [Ashfaq et al. 2019, Table 2]. Variable sizes at maturity across sites were used to validate and adjust minimum landing sizes (MLS) for regularly fished areas on Banquereau and Middle banks. There is still a need to refine methods for determining maturity and expand the data to include both sexes for each site. Differences in size-at-maturity exist between sexes and could influence the setting of MLS for a particular population. Female maturity was not consistently reported due to difficulty in determination. A refinement of the gonadosomatic index used by Ashfaq et al. (2019), or adopting a different index, may improve accuracy. Given that most indices rely on differentiating reproductive anatomy, sampling prior to egg laying, when differentiation is most pronounced, would also improve accuracy. However, the temporal patterns in the reproductive cycle of whelk for 4Vs and 4W are not currently defined. There is substantial information on the timing of reproduction in the Gulf of St. Lawrence; however, no studies currently exist that can confirm whether whelk follow the same reproductive pattern in this region. Given that whelk egg capsules were found attached to traps, it can be presumed that fishing is occurring during (and potentially prior to) periods of egg laying.

Age-at-maturity for whelk, as determined by counting striae on the operculum, similarly exhibited spatial variability despite data being inconsistently reported for sites and sexes (Ashfaq et al. 2019). It was not reported whether age was determined using the dorsal or ventral surface (the latter containing adventitious layers that do not develop as a function of age) of the opercula. The differing age-at-maturity indicates that these potential subpopulations may have different capacities for recovery. Licence holders indicated that growth rates are currently being investigated but have not been published to date.

Similar to age- and size-at-maturity, mean whelk size differed among the 5 sites (Ashfaq et al. 2019). These size-frequency distributions are representative of the catch but not necessarily the population due to gear being selective for whelk larger than 40 mm shell length (SL). Increasing selectivity of gear for smaller individuals would improve estimates of size structure, particularly for detecting recruits. Differentiation between sexes should also be considered when estimating size structure, particularly for females. Given that fecundity is relative to body size, a reduction in the proportion of larger mature females will lead to a lower reproductive output for the respective subpopulations.

Table 2. Sex ratio, smallest size-at-maturity, size at which 50% of whelk are mature (LM_{50}), and age-at-LM_{50} of Waved Whelk (Buccinum undatum) sampled at five sites on the Scotian Shelf between 2016 and 2017. Reproduced from Ashfaq et al. (2019). ND=no data.

Site	Sex Ratio (M:F)	Smallest Mature (mm)		LM_{50} (mm)		Age-at-LM_{50} (yrs.)	
		M	F	M	F	M	F
Southern Area 1 (4Vs)	1:1.3	50	ND	55.6	ND	6.2	ND
Northern Area 1 (4Vs)	1.8:1	50	ND	45.0	ND	5.1	ND
Southeastern Banquereau (4Vs)	1:1.4	45	46	55.2	57.1	5.4	5.7
Middle Bank (4W)	1:1	56	63	64.3	65.0	ND	6.4
Northeastern Banquereau (4Vs)	1:2.0	48	54	49.6	53.6	ND	ND

Population Structure

Research conducted in the Maritimes Region strongly suggests that there is local adaption and potential genetic differences among whelk populations, even at very small spatial scales. On Banquereau, for instance, differences in size- and age-at-maturity, parasite load, and mean size of catch were observed when compared between two sites separated by only 15 km (Ashfaq et al. 2019). Continued research in this area would identify subpopulations and contribute to the establishment of biologically relevant management areas to better ensure the sustainability of the resource. Currently, this is being accomplished through assessment of life-history traits but could also be examined through genetic analysis. This is being explored by industry and academic partners. Management areas should be continually refined as data become available.

Alternative Data Sources for Monitoring Stock Status

At present, there are no independent surveys for whelk in the Maritimes Region. The DFO groundfish survey does catch some whelk; however, these data are likely limited to identifying the broad-scale spatial extent of whelk populations. The gear used in the survey is not designed to capture whelk, particularly those which would be quiescent and buried, thus sampling would underestimate abundance and provide potentially biased size frequencies.

Another method, which is used in Quebec to conduct independent surveys, would be the use of a Digby scallop dredge. This method is more efficient at capturing quiescent whelk and, thus, catch would provide a more accurate reflection of natural parameters such as size frequency and abundance.

Potential Risks to Whelk Populations When Developing Management Strategies

As concluded in a large body of scientific literature, understanding the population structure of whelk is of paramount importance when properly managing whelk resources. The low dispersal potential due to adult behaviour and lack of dispersive larval stages make this species vulnerable to over-exploitation and likely slow to recover. A lack of understanding with regards to spatially variable life-history traits, such as size-at-maturity, has already resulted in the setting of standardized MLS values in different parts of the world that are inappropriate for subpopulations attaining sexual maturity at considerably larger sizes. The implementation of management practices should be conducted at a biologically relevant scale (i.e., for each subpopulation).

Whelk fishing using traps has been shown to have low impact on released whelk. Other demersal fishing activities, such as beam trawl fishing, can result in greater damage to caught whelks when compared to trap fishing and lower survival regardless of damage (Mensink et al. 2000). Predation risk is also increased due to behavioural changes when fishing activities cause a “rolling” of whelk (Ramsay and Kaiser 1998). Areas where fishing for whelk overlaps with demersal activities of other fishing gear may encounter greater mortalities.

Sources of Uncertainty

The CPUE values calculated in this document do not include a complete dataset due to missing effort and/or landing values. These values also do not incorporate soak time, which is currently only available at the coarse resolution of days rather than hours. Abundance and biomass are currently unknown due to difficulties in obtaining accurate estimates with the available methods. Natural mortality rates are similarly unknown. Additionally, the contribution of the sympatric whelk species, *C. stimpsoni*, to the landings have been considered low but have not historically been assessed.

In terms of life-history traits, the temporal patterns in the reproductive cycle of whelk for 4Vs and 4W are not currently defined. Data are available for size and age-at-maturity for several discrete locations; however, these are not fully described for both sexes across those locations. The description of subpopulations and their spatial extent, as informed by variable life-history traits, is similarly not fully described.

CONCLUSIONS AND ADVICE

The Whelk Monitoring Document, provided by Fisheries and Oceans Canada (DFO) to the fishers, is adequate for recording the majority of metrics that will be used when developing an assessment framework, particularly the spatial extent of the resource, total landings, and CPUE. Moving forward, however, there is a need to ensure consistent reporting/recording of data on the Monitoring Document. It is particularly important to record effort and soak time for each string to be able to accurately calculate CPUE.

More accurate differentiation between whelk species within the catch is necessary. Stimpson’s Whelk appear to constitute a low proportion of the catch; however, this should be verified. The spatial variability of Stimpson’s Whelk in the catch should also be determined.

Abundance and biomass estimates would aid in the development of a future stock assessment model. A stratified dredge survey, such as that conducted in the Quebec Region, could provide a more accurate estimate of these parameters.

A number of modifications to data collection and methods would improve the assessment of life-history traits and size structure. The collection of unbiased samples is needed to determine size structure and can be achieved by lining traps with fine mesh to prevent the escape of small individuals, thus ensuring no size selectivity. For the analyses of age-at-maturity and size-at-maturity, targeting of sampling to periods when differentiation of reproductive organs is greatest (i.e., prior to spawning), particularly for females, would reduce potential error in determination of maturity. It would also be beneficial to validate these methods using histological methods on a subset of samples. Aging whelk using striae (specifically the dorsal surface) on the operculum can be complicated and could be validated by observations of statoliths or chemical analysis (Hollyman et al. 2018). It is also beneficial to ensure consistency in these measures between industry members as variability can occur among different methods for determining age and maturity.

Determining temporal patterns of the reproductive cycle for whelk in this geographic region will not only provide a more appropriate temporal window when sampling for size- and age-at-maturity but also identify periods when catches are likely to be minimized due to decreased feeding activities during reproduction. The commencement of fishing activities after spawning will ensure that all females within the population have the opportunity to breed that season, increasing the potential reproductive output of the species.

Knowing that this species likely exhibits population structure over small spatial scales in 4Vs and 4W NAFO areas, and that whelk have a limited capacity for connectivity, a critical priority will be continuing to refine biologically appropriate management areas as information becomes available. These management areas could be delineated based on the extent of each subpopulation (a unit of whelk that does not receive significant, or potentially any, recruitment from adjacent subpopulations). This would apply even when there are no obvious boundaries between subpopulations. Delineation of management units could be accomplished through genetic analysis as prioritized by industry, but should also be accompanied by stratified sampling for whelk and assessing life-history traits and size structure. This latter sampling should also be consistently monitored for each management area. The data collected will be necessary to set MLS values for each respective area and could in turn be used for population modelling as part of a monitoring framework.

Whelk are vulnerable to over exploitation and local depletion, which can lead to the loss of subpopulations. To properly ensure sustainability in the fishery, whelk cannot be treated as a single stock for 4Vs or for 4W but, rather, each subpopulation should be managed separately, with individual MLS values and trends in metrics of CPUE and landings monitored independently. The extent of fishing effort for each management area should also be dispersed across the entire area, rather than concentrated, to ensure there is no local depletion. Concentrated fishing effort could also result in reducing the ability to detect decreases in CPUE, a potential monitoring indicator, particularly when the positioning of effort changes yearly.

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SOURCES OF INFORMATION

This Science Advisory Report is from the February 19, 2020, Development of a Monitoring Framework for the establishment of a Commercial Whelk Fishery in the Maritimes Region (4Vs and 4W). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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