

47 Abstract

48
49 The dogwhelk *Nucella lapillus* is a rocky intertidal gastropod of the North Atlantic coast.
50 Individual shell color varies. Common colors range between white and brown, with darker
51 dogwhelks being more affected by heat stress than lighter-colored conspecifics. Other reported
52 shell colors are black, mauve, pink, yellow, and orange from European coasts, red and grey from
53 the Bay of Fundy coast of New Brunswick and Nova Scotia (Canada), and purple, black, gray,
54 yellow, and orange from the coasts of Maine and Massachusetts (USA), with purple being
55 considered as a rare color. On the Atlantic coast of Nova Scotia, dogwhelks are active from April
56 until November, but information on dogwhelk shell color is missing for this coast. On 16 June
57 2016, we found two purple dogwhelks in the mid-to-high intertidal zone of a moderately wave-
58 exposed rocky shore near Duncans Cove, on the Atlantic coast of Nova Scotia while collecting
59 dogwhelks (n= 1000) for manipulative field experiments. All other dogwhelks collected on that
60 day were of common white and brown colors. During earlier dogwhelk collections in Atlantic
61 Nova Scotia (between 2011-2013) and field surveys in Duncans Cove (between 2014-2016), we
62 did not find any purple dogwhelks, indicating the rareness of this color in that region.
63 Interestingly, the purple dogwhelks were detected on a relatively cool day (12.3 ± 0.4 °C, mean \pm
64 se, n= 96 temperature measurements) compared to the intertidal temperatures of all other survey
65 days ($\geq 18.2 \pm 0.5$ °C), suggesting that purple dogwhelks may find it less thermally stressful to
66 venture out of crevices and macroalgal cover under relatively cool temperatures. Our
67 observations provide the first visual record of rare purple dogwhelks on the Atlantic coast of
68 Nova Scotia, Canada.

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70 Keywords

71 dogwhelk, *Nucella lapillus*, color, snail, rocky intertidal, rareness, temperature

72 Introduction

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74 The dogwhelk *Nucella lapillus* (L. 1758) is a common predatory gastropod in the rocky intertidal
75 of the North Atlantic (Crothers 1985, Etter 2007). Individuals vary in shell color. White and
76 brown are common colors (Berry & Crothers 1974, Crothers 1983, Crothers 1985, Etter 1988),
77 with darker dogwhelks being more affected by physiological stress under high temperatures than
78 lighter-color conspecifics caused by higher energy intake from sunlight (Etter 1988). Other shell
79 colors reported are black, mauve, pink, yellow, and orange on European coasts (Moore 1936,
80 Berry & Crothers 1974), red and grey from the Bay of Fundy coast of New Brunswick and Nova
81 Scotia (Canada) (Colton 1922, Crothers 1983), and black, purple, gray, yellow, and orange from
82 the coasts of Maine (Colton 1922, Crothers 1983) and Massachusetts (USA) (Etter 1988). Purple
83 is considered to be a rare color in dogwhelks (Colton 1922, Etter 1988). On the Atlantic coast of
84 Nova Scotia, dogwhelks are active from April until November (Hughes 1972, Hunt & Scheibling
85 1998), but information on dogwhelk shell colors is missing for this coast.

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87 Methods

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89 On 16 June 2016, we collected 1000 dogwhelks along 300 m of coastline in the mid-to-high
90 intertidal of a moderately wave-exposed rocky shore near Duncans Cove (44°29'41.22"N, 63°

91 31°26.66'W), Halifax on the Atlantic coast of Nova Scotia. The dogwhelks were collected for
92 manipulative field experiments to examine nonconsumptive effects (NCEs) of these predators on
93 their prey. Equal dogwhelk quantities were collected by one of us (JAE) for related research
94 projects on dogwhelk NCEs (e.g. Ellrich et al. 2015, 2016) in several locations, with similar
95 levels of intertidal elevation and wave-exposure, along the Atlantic coast of Nova Scotia: in
96 Glasgow Head (45°19'12.61"N, 60° 17'34.15"W) in May and June 2011, in Deming Island
97 (45°12'44.31"N, 61° 10'25.99"W) in May 2012, and in Deming Island, Halfway Cove
98 (45°20'58.98"N, 61° 21'46.58"W), and Half Island Cove (45°21'19.77"N, 61° 11'23.73"W) in
99 May and June 2013.

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101 During field surveys for another research project near our dogwhelk collection site in Duncans
102 Cove, dogwhelk colors were observed regularly (on 12 August 2014, 1 September 2015, and 21
103 August 2016). To observe dogwhelk colors, 30 quadrats (25 cm x 25 cm) along a ~150 m
104 transect parallel to the coastline were sampled at random on each survey date. Throughout the
105 entire survey period, intertidal temperature was measured continuously every 30 minutes by two
106 submersible loggers (HOBO Pendant Logger, Onset Computer Corp., Pocasset, MA, USA).
107 Using temperature data from those loggers, we calculated the average intertidal temperature for
108 the all the dates when dogwhelks were collected or observed in Duncans Cove.

109 **Results & Discussion**

110 In our collection of dogwhelks near Duncans Cove on 16 June 2016 (n= 1000 dogwhelks), we
111 found two dogwhelks of purple shell color. Our results provide the first visual record of purple
112 dogwhelks on the Atlantic coast of Nova Scotia (Figure 1). The other dogwhelks collected on
113 that day were of common white and brown shell colors. We did not find any other purple
114 dogwhelk during any of our five collections of equal dogwhelk quantities along the Atlantic
115 Coast of Nova Scotia (n= 5000 dogwhelks of brown and white shell color in total) or three field
116 surveys near Duncans Cove (n= 82 dogwhelks of brown and white shell color in total) indicating
117 that purple dogwhelks are rare in that region.

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119 Comparing the average intertidal temperatures of the dogwhelk collection day (12.3 ± 0.4 °C,
120 mean \pm se, n = 96 temperature measurements, 16 June 2016) and the three dogwhelk observation
121 days (19.5 ± 0.7 °C, 12 August 2014; 18.2 ± 0.5 °C, 1 September 2015; 22.3 ± 0.5 °C, 21 August
122 2016) in Duncans Cove revealed that the purple dogwhelks were found on a relatively cool day.
123 This suggests that purple dogwhelks may find it less thermally stressful to venture out of
124 crevices and macroalgal cover under relatively cool temperatures. Darker dogwhelks show
125 stronger physiological responses to heat, such as faster desiccation, than lighter-color
126 conspecifics (Etter 1988). Future experiments could, thus, examine if dogwhelk behavioural
127 responses to temperature are related to shell color, which may contribute to the rareness in the
128 observed purple dogwhelks.

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138 **Figure 1. A purple dogwhelk, *Nucella lapillus* (L. 1758).** Picture taken near Duncans Cove
139 (44°29'41.22"N, 63° 31'26.66"W), Halifax on the Atlantic coast of Nova Scotia, Canada on 16
140 June 2016 (picture credit: Julius A. Ellrich).

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143 **Supplementary files**

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145 Intertidal Temperatures 12-Aug-2014:

146 Intertidal temperatures measured by temperature loggers 1 & 2 on 12-Aug-2014 every 30
147 minutes

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149 Intertidal Temperatures 01-Sep-2015:

150 Intertidal temperatures measured by temperature loggers 1 & 2 on 01-Sep-2015 every 30 minutes

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152 Intertidal Temperatures 12-Jun-2016:

153 Intertidal temperatures measured by temperature loggers 1 & 2 on 12-Jun-2016 every 30 minutes

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155 Intertidal Temperatures 21-Aug-2016:

156 Intertidal temperatures measured by temperature loggers 1 & 2 on 21-Aug-2016 every 30
157 minutes

158 **Author contributions**

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160 SME and JAE conducted the field work. JAE wrote the manuscript and SME provided critical
161 comments to produce the final version.

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163 **Competing interests**

164 No competing interests were disclosed.

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