Overall, results from the 2017 and 2018 narwhal tagging study supported predictions made in the FEIS for the ERP, in that ship noise effects on narwhal will be limited to temporary, short-term avoidance behaviour, consistent with low to moderate severity responses (Southall et al. 2007; Finneran et al. 2017). No evidence was observed of large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a non-significant effect used in the FEIS).

8.0 COMBINED EFFECTS ASSESSSMENT

In their Final Written Submissions (DFO 3.11 (October 2019) and DFO 3.7 (January 2020)), DFO requested that Baffinland conduct an assessment examining all combined effects of the Project. Table 22 addresses this request, and considers both Project incremental and Project combined effects for each marine mammal VEC based on the five key effect pathways identified: vessel strikes, entrapment in ice, acoustic injury, acoustic behavioural disturbance and acoustic masking from shipping operations, along with a determination of significance. A detailed description of the assessment methodology is provided in FEIS Volume 2, Section 3, including the approach used for characterizing residual effects and determining significance.

The previous effects assessment submissions have demonstrated that, following implementation of known and effective mitigation measures, three of these effect pathways (vessel strikes, entrapment and acoustic injury) are not predicted to occur and hence are not predicted to act in combination with the two remaining effect pathways (acoustic disturbance and acoustic masking).

Regarding the combined effect of behavioral disturbance and acoustic masking, it is important to note that acoustic masking is actually a form of behavioural disturbance, with masking effects occurring at the lower level of behavioural impacts in marine mammals (Pine et al. 2018). In essence, these two pathways are already inherently combined, as shown by the identical effect ratings and significance determinations in Table 22. While limited masking from ship noise is predicted to occur for marine mammals in the RSA as demonstrated through acoustic modelling, the levels are comparable to those animals in the RSA already regularly experience from ambient noise sources (i.e., natural weather events), and it is not presently possible to determine or calculate the biological consequence of this effect, if one exists.

Table 22: Updated residual effect ratings and significance determinations for Marine Mammal VECs - Phase 2

Residual Effect	Residual Effect Evaluation Criteria					Significance	Qualifiers**	
	Magnitude	Extent	Frequency	Duration	Reversibility		Probability (Likelihood of Effect Occurring)	Certainty (Confidence in Effects Prediction)
Narwhal (BB and ES*)								
Hearing impairment	-	-	-	-	-	-	I (Unlikely)	III (High)
Disturbance	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Acoustic masking	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Ice entrapment	Level I	Level I	Level I	Level II	Level I	N	I (Unlikely)	III (High)
Ship strikes	Level I	Level I	Level I	Level II	Level I	N	I (Unlikely)	III (High)

Residual Effect	Residual Effect Evaluation Criteria					Significance	Qualifiers**	
	Magnitude	Extent	Frequency	Duration	Reversibility		Probability (Likelihood of Effect Occurring)	Certainty (Confidence in Effects Prediction)
Combined Project Effects	Level II	Level II	Level II	Level II	Level I	N		II (Medium)
Beluga								
Hearing impairment	-	-	-	-	-	-	I (Unlikely)	III (High)
Disturbance	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Acoustic masking	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Ice entrapment	Level I	Level I	Level I	Level II	Level I	N	I (Unlikely)	III (High)
Ship strikes	Level I	Level I	Level I	Level II	Level I	N	I (Unlikely)	III (High)
Combined Project Effects	Level II	Level II	Level II	Level II	Level I	N		II (Medium)
Bowhead whale								
Hearing impairment	-	-	-	-	-	-	I (Unlikely)	III (High)
Disturbance	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Acoustic masking	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Ship strikes	Level I	Level I	Level I	Level II	Level I	N	I (Unlikely)	III (High)
Combined Project Effects	Level II	Level II	Level II	Level II	Level I	N		II (Medium)
Ringed seal								
Hearing impairment	-	-	-	-	-	-	I (Unlikely)	III (High)
Disturbance	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Acoustic masking	Level II	Level II	Level II	Level II	Level I	N	II (Moderate)	II (Medium)
Ship strikes	Level I	Level I	Level I	Level II	Level I	N	I (Unlikely)	III (High)
Change in habitat	Level I	Level I	Level II	Level II	Level I	N	I (Unlikely)	III (High)
Combined Project Effects	Level II	Level II	Level II	Level II	Level I	N		II (Medium)
Polar bear								
Ship strikes	Level I	Level I	Level I	Level II	Level I	N	I (Unlikely)	III (High)
Combined Project Effects	Level 1	Level1	Level 1	Level II	Level I	N		III (High)

Notes:
Magnitude: 1 (Level I) = an effect on the exposed indicator/VEC that results in a change that is not distinguishable from natural variation and is within regulated values; 2 (Level II) = an effect that results in some exceedance of regulated values and/or results in a change that is measurable but allows recovery within one to two generations; 3 (Level III) = an effect predicted to exceed regulated values and/or result in a reduced population size or other long-lasting effect on the subject of the assessment.
Extent: 1 (Level I) = confined to the LSA; 2 (Level II) = beyond the LSA and within the RSA; 3 (Level III) = beyond the RSA
Frequency: 1 (Level I) = infrequent (rarely occurring); 2 (Level II) = frequent (intermittently occurring); 3 (Level III) = continuous
Duration: 1 (Level I) = short-term (<5 years); 2 (Level II) = medium-term (life of Project); 3 (Level III) = long-term (beyond the life of the project) or permanent
Reversibility: 1 (Level I) = fully reversible after activity is complete; 2 (Level II) = partially reversible after activity is complete; 3 (Level III) = non-reversible after the activity is complete. Note: Reversibility is considered for biological VECs at the population level. Therefore, although an effect like mortality is irreversible, the effect at the population level might be reversible.
Significance Rating: S=Significant, N=Not Significant, P=Positive
Qualifiers- only applicable to significant effects**
Probability: 1 (Level I) = unlikely; 2 (Level II) = moderate; 3 (Level III) = likely
Certainty: 1 (Level I) = low; 2 (Level II) = medium; 3 (Level III) = high
*BB: Baffin Bay population; ES: Eclipse Sound summer stock (sub-population)
**Qualifiers provided for at the request of DFO. Inclusion is not consistent with FEIS methodology that indicates qualifiers are only applicable to significant effects.

With the effective implementation of mitigation measures currently in place (e.g., 9 knot speed restriction, 40-km buffer zone, limited icebreaker transits during shoulder season, etc.), it is predicted that the residual combined effects of the Project on marine mammals in the RSA will be limited to temporary and localized avoidance behavior. In summary, when all potential effects on marine mammals are combined, no significant residual effects are predicted for any of the marine mammal VECs in the RSA, that is no effects at the population or stock level, either through mortality or from large-scale displacement or abandonment from the RSA, are anticipated.

9.0 SUMMARY

Baffinland's marine mammal monitoring programs were based on a comprehensive 'multiple lines of evidence' approach for detection of potential Project effects, using an integrated combination of remote sensing and shore-based, vessel-based, aerial-based and acoustic-based monitoring methods. Collectively, these multi-year monitoring programs provided a comprehensive evaluation of potential shipping effects on marine mammals during the shipping period. Potential effects on marine mammals detected as part of this process were evaluated against impact predictions made in the FEIS, and in light of the various mitigation measures presently implemented as part of Baffinland's current shipping operations.

Overall, monitoring results collected to date, in concert with available modelling data, supported impact predictions made in the FEIS Addendum for ERP shipping operations, in that no marine mammal mortalities are anticipated to occur in the RSA from ship strikes, and that acoustic impacts from shipping on marine mammals will be limited to temporary, short-term avoidance behaviour, consistent with low to moderate severity responses (Southall et al. 2007; Finneran et al. 2017). Through the monitoring programs, no evidence has been observed of large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (consistent with high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a non-significant effect used in the FEIS).

10.0 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional information, please contact the undersigned.

Golder Associates Ltd.

Phil Rouget, MSc, RPBio
Senior Marine Mammal Biologist

Bart DeFreitas, MSc, RPBio, PMP
Associate, Senior Biologist

PR/BAF/lih

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Appendix 4

2018 Tagged Narwhal During Icebreaking

GOLDER

TECHNICAL MEMORANDUM

DATE 15 October 2019 **Reference No.** 1663724-162-TM-Rev0-12000

TO Megan Lord-Hoyle
Baffinland Iron Mines Corporation

CC

FROM Phil Rouget **EMAIL prouget@golder.com**

MOVEMENT OF TAGGED NARWHAL (MONODON MONOCEROS) IN RELATION TO ICEBREAKING OPERATIONS AND ASSOCIATED VESSEL TRAFFIC DURING THE 2018 FALL SHOULDER SEASON

Golder Associates (Golder) partnered with Fisheries and Oceans Canada (DFO) in 2017 and 2018 to undertake a narwhal tagging study based out of Tremblay Sound in the North Baffin Region of Nunavut. The collaborative research program involved Golder expanding on DFO's existing tagging program by supplying additional biologging tags that were customized to address Baffinland's Project-specific study objectives related to understanding behavioural response of narwhal to vessel traffic.

This technical memorandum presents a limited scope relative to this program and has been prepared in response to commitments made by Baffinland Iron Mines Corporation (Baffinland) to assess narwhal (*Monodon monoceros*) behavioral response to Project-related icebreaking operations in support of the Mary River Project (the Project) Phase 2 proposal.

1.0 BACKGROUND

Two narwhal were tagged with a combination of GPS Fastloc location tags (CTD-SRDL; SMRU), pop-up archival dive tow tags (MiniPAT/Mk10PAT; Wildlife Computers), and passive acoustic recording tags (Acousonde 3MB; Greenridge Sciences) during the 2018 Tremblay Sound Narwhal Tagging Program. Both individuals were tagged on 17 August 2018, with narwhal NW21 transmitting ARGOS location data until 08 October 2018 (53 days) and narwhal NW22 transmitting GPS Fastloc location data until 02 November 2018 (76 days). Dive and acoustic data collected for NW21 (24 and 3 days, respectively) and NW22 (20 and 7 days, respectively) did not extend into the fall shoulder season. Therefore, to assess narwhal behavioral response to icebreaking operations and associated vessel traffic, this technical memorandum is focused solely on narwhal positional data collected between 29 September and 17 October 2018, coincident with the period the MSV *Botnica* (97-m icebreaker) was conducting Project-related icebreaking operations along the Northern Shipping Route in the Regional Study Area (RSA) (Figure 1).

Given the limited data presented in this report, the sample size is insufficient for a comprehensive statistical analysis to be undertaken. Instead, narwhal interactions with icebreaking operations and associated vessel traffic are presented for the purpose of visualizing and qualitatively discussing potential behavioral responses of narwhal to icebreaker transits in the RSA during the 2018 fall shoulder season. Statistical analysis of the full extent of the tagging data (i.e., all tags) will be undertaken as part of the 2017/2018 integrated tagging report, which will build on information presented in the 2017 Narwhal Tagging Study – Technical Data Report (Golder 2018). The integrated tagging report will be provided in draft form to the Marine Environmental Working Group (MEWG) in Q1 of 2020.

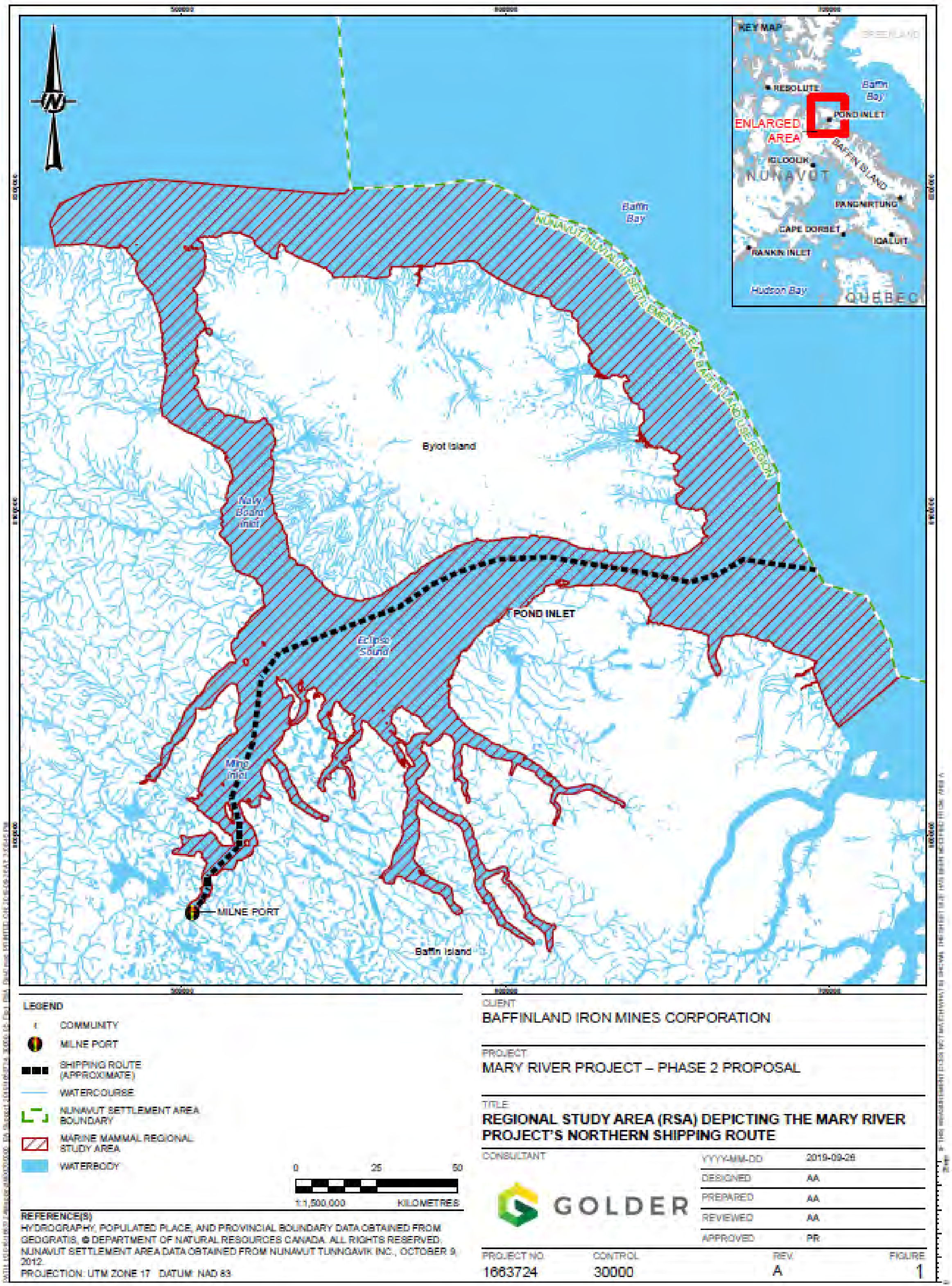

Figure 1: Regional Study Area (RSA) depicting the Mary River Project's Northern Shipping Route

2.0 METHODS

2.1 Narwhal GPS Data Management

Narwhal positional data presented in this technical memorandum were obtained from CTD-SRDL GPS location tags. The CTD-SRDL tag is an ARGOS satellite tag manufactured by Sea Mammal Research Unit (SMRU) Instrumentation that includes sensors to measure horizontal and vertical movement, as well as record water temperature, conductivity, and wet/dry periods to decipher surfacing events. Data collected by the CTD-SRDL tags are summarized and compressed for transmission each time the animal surfaces. Depth data collected by the CTD-SRDL is associated with individual dives and pre-determined depth intervals, not recorded at specific time intervals as in the MiniPAT, Mk10-Pat and Splash-10 tags (Wildlife Computers). Both CTD-SRDL tags were attached to narwhal using a 'backpack' style design with three nylon pins inserted subdermally on the back of the animal.

To reduce erroneous locations, GPS data were filtered to remove all narwhal positions calculated from less than six satellite positions and for which the residual value was ≤30 (Dujon et al. 2014). Where gaps in GPS locations were evident, narwhal positional data were interpolated at 1-min intervals and only raw GPS data or interpolated data within 20 min from a raw GPS point were used for this study. Further details on the approach undertaken to manage narwhal positional data is presented in Golder (2018).

Although both tags deployed on NW21 and NW22 included Fastloc GPS capability, only lower-resolution ARGOS location data were available for NW21 during the fall shoulder season (Fastloc data stopped transmitting several weeks earlier). As such, daily movements of both animals in relation to icebreaking operations and associated vessels are presented for visualization purposes (Appendix A) but location data associated with NW21 is of insufficient resolution to assess behavioral responses during the animal's closest point of approach (CPA) with icebreaking vessels (see Section 2.3).

2.2 Vessel AIS Data Management

Vessel GPS data used in this study were a combination of shore-based and satellite-based Automated Identification System (AIS) data, which provided accurate real-time data on all large vessel passages along the Northern Shipping Route during the 2018 shipping season. AIS is mandatory for all commercial vessels >300 gross tonnage and passenger ships. A shore-based AIS station was installed on a high cliff near Bruce Head, which provided a continuous record of ship positions within line-of-sight of the station, inclusive of Milne Inlet (north and south) and portions of Eclipse Sound and Navy Board Inlet. A second shore-based AIS station in Pond Inlet provided a continuous record of ship positions for the eastern portion of Eclipse Sound and Pond Inlet. Satellite-based AIS data, acquired from exactEarth Ltd[1], was used to supplement vessel position information during periods when there were gaps in the shore-based data. The temporal resolution of the shore-based AIS data was approximately five seconds, whereas the satellite-based AIS data exhibited longer interposition times (ten minutes on average), resulting in a comparatively lower spatial and temporal resolution with respect to vessel position. To best represent vessel movement in the along the Northern Shipping Route during periods when only satellite-based AIS was available, vessel position was interpolated at one-minute intervals.

[1] exactEarth Ltd. Is a data services company that leverages advanced microsatellite technology and globally deployed ground systems to deliver exactAIS™, a global vessel tracking and monitoring system based on world leading space-based advanced AIS detection technology.

Vessels were classified into three categories – small vessels (<50 m in length), medium vessels (≥50 m but <100 m in length), and large vessels (≥100 m in length). For non-icebreaking vessels present in the RSA, only large vessels (≥100 m in length) were used in subsequent analyses. Two icebreaking vessels were present in the RSA during the 2018 fall shoulder season, one procured by Baffinland to provide escort to ore carriers (the MSV Botnica), and another 88-m icebreaker that was not Project-related (Canadian Coast Guard Service (CCGS) Terry Fox). AIS data were filtered to retain only transiting vessels (speed ≥1 knot), to avoid representing interactions between narwhal and stationary vessels.

2.3 Identification of Closest Point of Approach (CPA) Events

Horizontal movements of the single narwhal (NW22) outfitted with a GPS Fastloc tag were analyzed in relation to AIS vessel track data to determine the location and time of narwhal-vessel interactions. Using customized functions in R v. 3.6.1 (R Core Team 2019), the closest point of approach (CPA) was identified for all 'events[2]' in which vessels transiting along the Northern Shipping Route were within 54.4 km of the animal. This distance (54.4 km) was selected based on acoustic modeling results by JASCO Applied Sciences (Quijano et al. 2019) which predicted icebreaker noise would extend above the 120 dB re: 1µPa (SPL_{rms}) disturbance threshold for distances up to 54.4 km (R_{max}), based on a modelled scenario of an icebreaker escorting two Capesize ore carriers through Eclipse Sound in 10/10 ice concentration.

For each narwhal GPS position, all vessel AIS positions recorded within the preceding or following 30 minutes of the timestamp were retrieved and the nearest AIS position to a given narwhal location was identified. Of these, the points in time when the distance between the narwhal and the vessel decreased and then increased were retrieved as potential CPA points. These "potential" CPA points were further assessed in a second step, so that only a single CPA point within each 6-h time period was retained. A CPA event was then defined as the ±3 h time window around each CPA timestamp. As a quality control measure, animations were created depicting real-time movements of NW22 in relation to transiting ships over the period of interest (29 September– 17 October 2018). Visual examination of the animations allowed the analyst to confirm individual CPA events and qualitatively assess the movements of NW22 in relation to icebreaking operations and associated vessel traffic in greater detail. For each CPA event (i.e., each narwhal-vessel interaction within ±3 h from a CPA point), two plots were then generated. The first plot included a zoomed-out map depicting the horizontal relocations of individual narwhal in relation to the vessel in the ±3 h from the CPA timestamp. The second plot included a zoomed-in map showing the finer resolution movements for the same narwhal during the same time period. All analyses and plotting were performed in R v.3.6.1 (R Core Team 2019).

3.0 RESULTS

3.1 Narwhal Interactions with All Vessel Types

Both NW21 and NW22 remained in the vicinity of the Northern Shipping Route for extended periods during the 2018 fall shoulder season, despite being exposed to thickening ice conditions, icebreaking operations and associated vessel traffic. Although the ARGOS location data associated with NW21 were not of sufficient resolution to assess fine scale movements of this animal in relation to icebreaker movements, it is evident from

[2] Event = the 6 h time period associated with each CPA (3 h before and 3 h after CPA), where the whale-vessel distance was ≤54.4 km along the Northern Shipping Route. Events more than 3 h apart, even of the same narwhal with the same vessel, are considered different events.

the daily narwhal tracks presented in Figures A-1 to A-19 (Appendix A) that exposure to icebreaker and ship traffic during this time did not result in displacement of either narwhal from the RSA.

In general, NW22 had multiple close encounters with all vessel types throughout the fall shoulder season and did not appear to actively avoid icebreaking operations and associated vessel traffic as the season progressed (Figure 2). A total of 84 CPA events were identified in which NW22 was within 54.4 km of active vessel transits. Of these, 26 events were with icebreakers, 47 with ore carriers, 6 with fuel tankers, and 5 with cargo vessels. NW22's closest encounters with the different types of Project vessels were as follows:

- Icebreaker: 0.84 km (15 October 2018; MSV *Botnica*)
- Ore carrier: 1.66 km (02 October 2018; *Nordic Orion*),
- Fuel tanker: 4.25 km (14 October 2018; *Sarah Desgagnés*)
- Cargo vessel: 1.32 km (10 October 2018; *Zelada Desgagnés*).

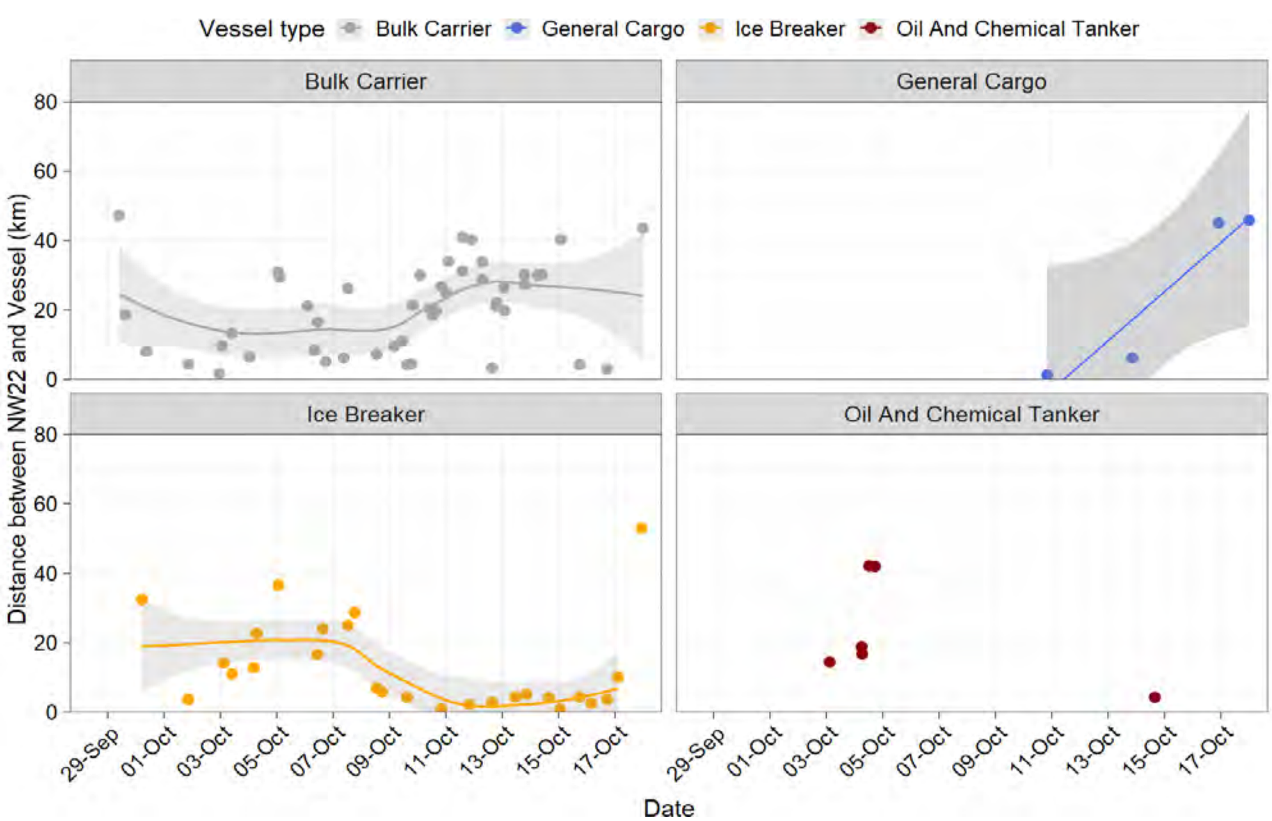

Figure 2: Closest points of approach (CPAs) of NW22 with different vessel classes during the 2018 Fall shoulder season (29 September - 17 October 2018)

3.2 Narwhal Interactions with Icebreaking Operations

Of the total 84 CPA events identified for NW22 within 54.4 km from active vessel transits, 25 events occurred in relation to icebreaking transits undertaken by the MSV *Botnica* and one event occurred in relation to icebreaking transits by the CCGS *Terry Fox* (Table 1; Figure 3 through Figure 11. Other Project-related vessels present during close encounters of NW22 with icebreaker transits are noted in Table 1 and presented as black hatched tracks in Figure 3 through Figure 11. In general, each of the 26 CPA events identified represents the closest encounter of NW22 with icebreaking operations during one active vessel transit in/out of Eclipse Sound, although transits by the icebreaker and associated vessel traffic did not always extend the full extent of the route between Milne Port and the eastern edge of the RSA (e.g. CPA events 1 and 7). The distance between NW22 and an icebreaker during active transits (CPA < 54.4 km) ranged between 0.84 km and 52.97 km.

Table 1: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking vessels. All CPA events presented are interactions of NW22 with the MSV *Botnica*, except for CPA event #6 which is an interaction of NW22 with the CCGS *Terry Fox*

CPA Event	Date	Time (UTC)	Average Vessel Speed (kts)	CPA Distance (km)	Ice Concentration @ CPA	Escort / Other Vessels Present
1	30 September 2018	5:16:24	8.1	32.47	< 1/10	Eastward with *Golden Ice* until CPA, then turned back westward while *Golden Ice* continued out of RSA.
2	1 October 2018	20:29:31	8.3	3.60	7-8/10	Eastward with NS *Yakutia*.
3	3 October 2018	02:43:24	8.8	14.21	< 1/10	Westward with *Sarah Desgagnés*; *Golden Opportunity also* nearby, heading westward; *Nordic Orion* also nearby, heading eastward.
4	3 October 2018	09:59:24	8.6	11.06	9-10/10	Eastward without escort; *Golden Pearl* also nearby, heading westward.
5	4 October 2018	04:27:24	8.7	12.78	9-10/10	Westward without escort. CCGS *Terry Fox* with *Kitikmeot W* and *Qikiqtaaluk W* also nearby, heading south from Navy Board Inlet; *Nordpol* also nearby.

CPA Event	Date	Time (UTC)	Average Vessel Speed (kts)	CPA Distance (km)	Ice Concentration @ CPA	Escort / Other Vessels Present
6	4 October 2018	06:46:24	6.2	22.69	9-10/10	South and then eastward with *Kitikmeot W* and *Qikiqtaaluk W*; *Botnica* also nearby, heading westward; *Nordpol* also nearby.
7	5 October 2018	1:30:24	7.9	36.58	9-10/10	Eastward with *Golden Opportunity* until CPA and then westward with *Golden Amber*.
8	6 October 2018	10:32:24	8.3	16.54	9-10/10	Eastward with *Golden Pearl*; *Nordic Odin* also nearby.
9	6 October 2018	15:04:24	8.4	23.99	9-10/10	Westward[3] without escort (departed *Golden Pearl* in middle of Eclipse Sound to return west). *Nordic Odin* also nearby.
10	7 October 2018	12:34:24	8.1	25.01	9-10/10	Eastward with *Nordpol*; *Nordic Odin* also nearby.
11	7 October 2018	18:26:24	8.3	28.61	9-10/10	Westward without escort (departed *Nordpol* in middle of Eclipse Sound to return west).
12	8 October 2018	12:56:24	8.4	6.96	9-10/10	Eastward with *Golden Amber*
13	8 October 2018	17:48:36	8.5	5.78	9-10/10	Westward without escort; *Golden Amber* moving eastward.
14	9 October 2018	14:51:24	6.9	4.23	9-10/10	Eastward with *Nordic Olympic*; *Nordic Odyssey* and *Arkadia* also nearby.

[3] Note that the arrow showing vessel direction of travel in Figure 5 does not point west due to the initial part of the track being oriented eastward.

CPA Event	Date	Time (UTC)	Average Vessel Speed (kts)	CPA Distance (km)	Ice Concentration @ CPA	Escort / Other Vessels Present
15	10 October 2018	20:02:24	7.0	0.95	9-10/10	Westward with *Zelada Desgagnés*; Nordic Odyssey and *Arkadia* also nearby.
16	11 October 2018	19:51:24	6.7	2.11	9-10/10	Eastward without escort; *Nordic Odyssey* and *Arkadia* also nearby.
17	12 October 2018	15:23:29	7.1	2.74	9-10/10	Westward with *Nordic Oshima*; *Nordic Odyssey* and *Arkadia* also nearby.
18	13 October 2018	11:10:24	7.7	4.37	9-10/10	Eastward without escort.
19	13 October 2018	20:34:24	7.8	5.14	9-10/10	Westward with *Qamutik*; *Nordic Odyssey* and *Arkadia* also nearby.
20	14 October 2018	15:39:24	8.3	4.11	9-10/10	Eastward with *Sarah Desgagnés*. *Nordic Odyssey* also nearby.
21	15 October 2018	1:12:24	8.1	0.84	9-10/10	Westward without escort. *Nordic Odyssey* also nearby.
22	15 October 2018	17:55:24	6.4	4.30	9-10/10	Eastward with *Nordic Odin*.
23	16 October 2018	04:02:24	7.9	2.53	9-10/10	Westward without escort.
24	16 October 2018	17:30:24	6.5	3.64	9-10/10	Eastward with *Nordic Oshima*
25	17 October 2018	02:39:24	8.2	10.02	9-10/10	Westward without escort; *Zelada Desgagnés* also nearby.
26	17 October 2018	22:36:24	7.6	52.97	7-8/10	Eastward with *Arkadia* and *Zelada Desgagnés*

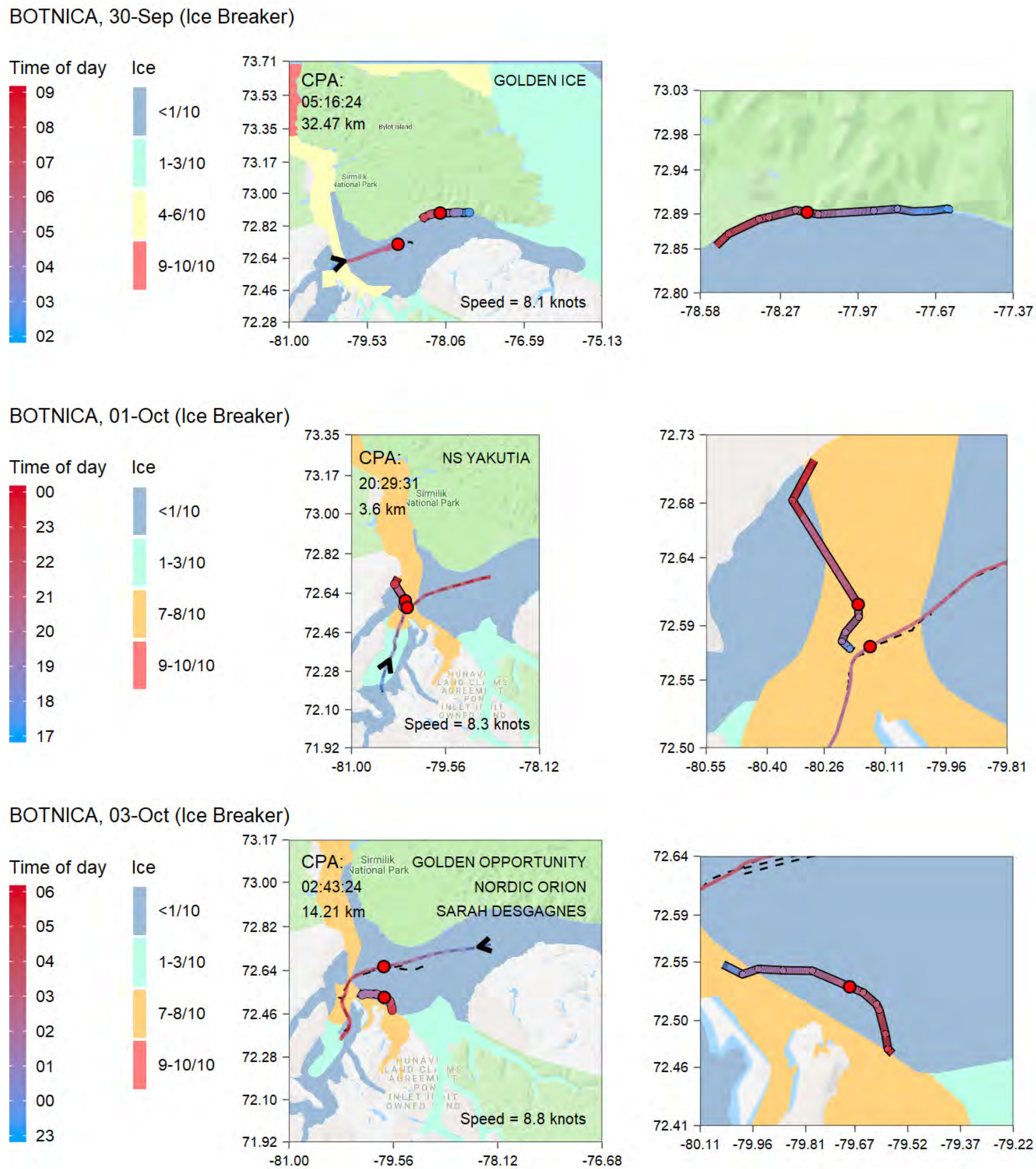

Figure 3: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 1 through 3). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

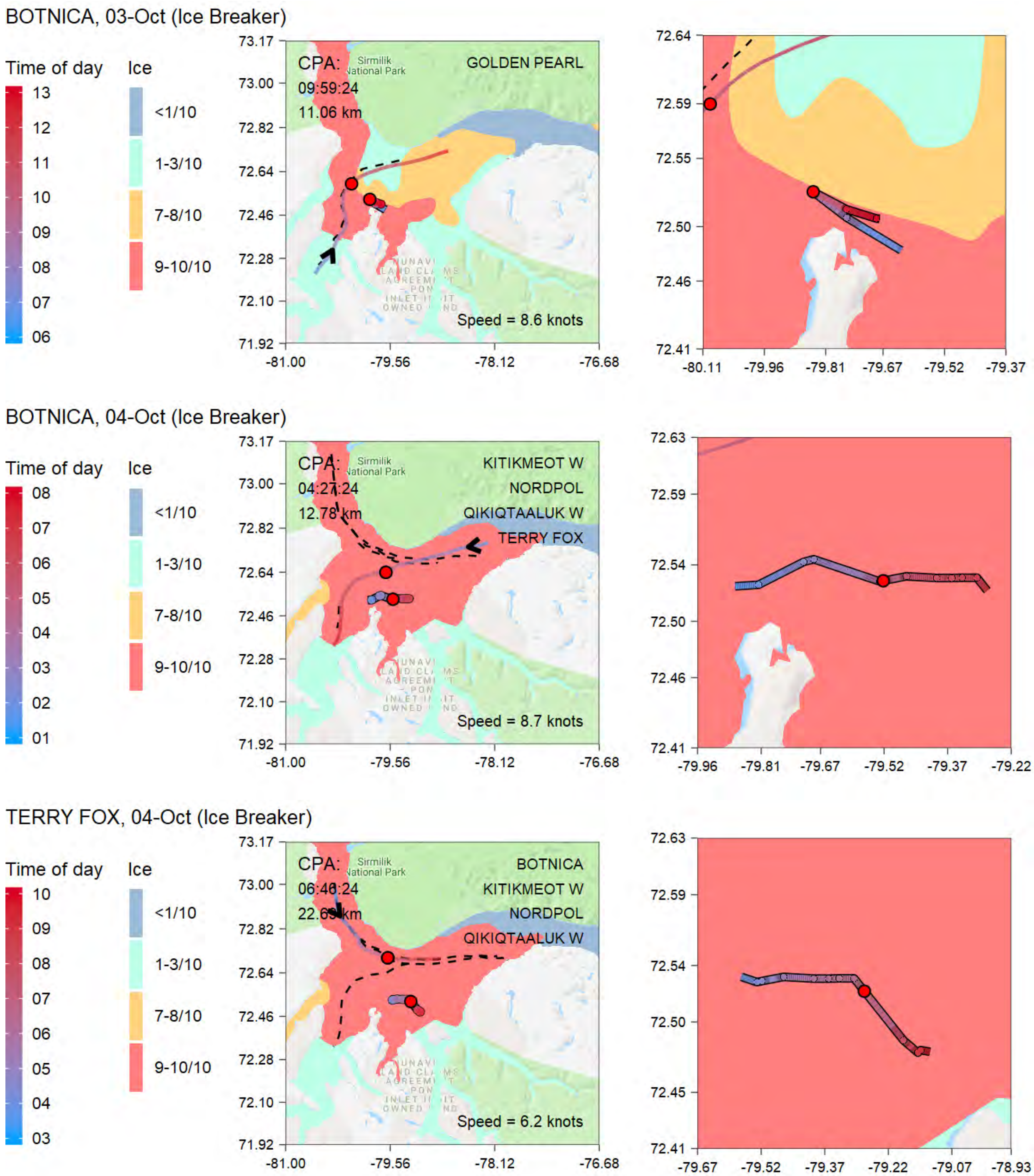

Figure 4: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 4 through 6). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

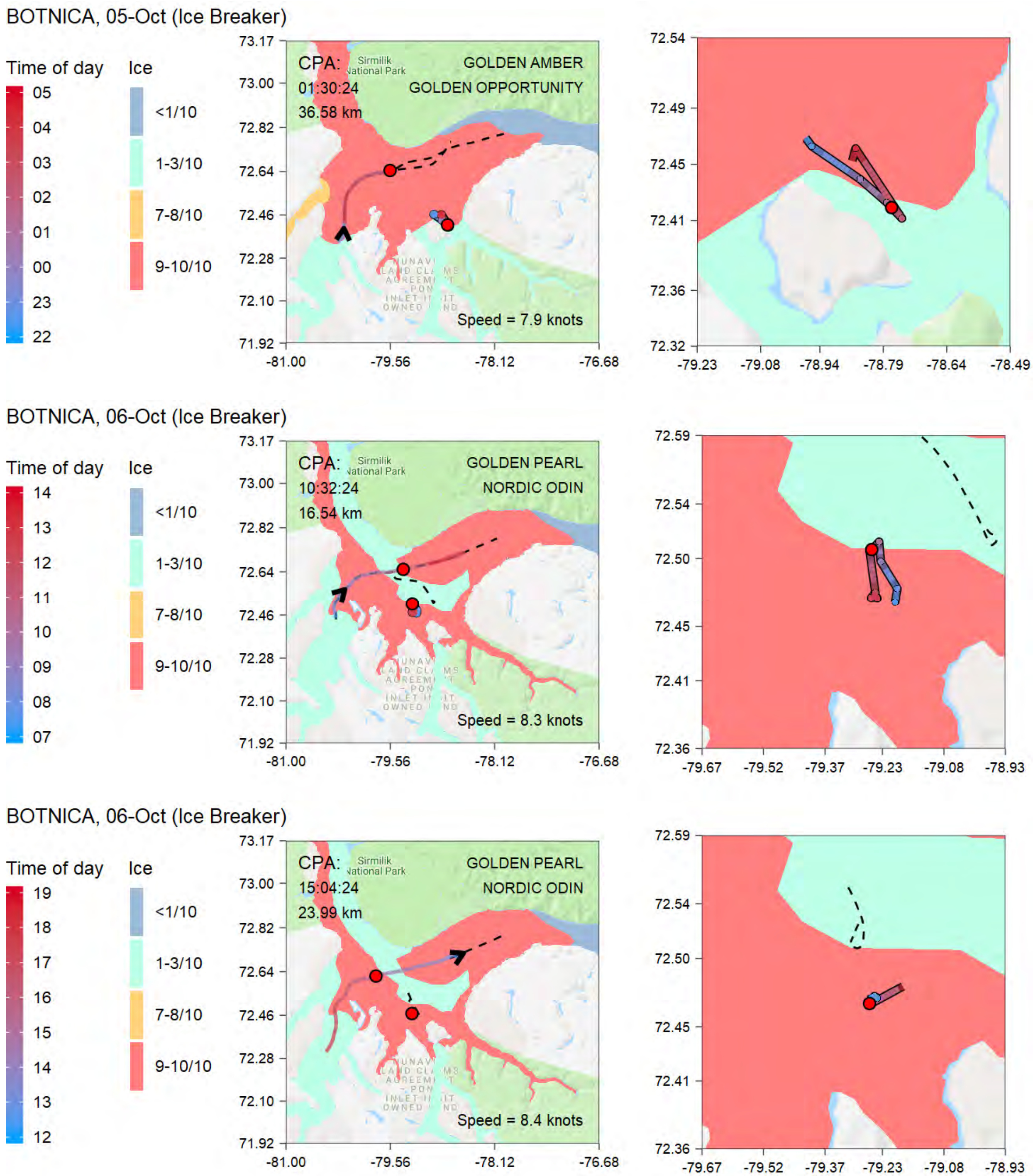

Figure 5: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 7 through 9). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

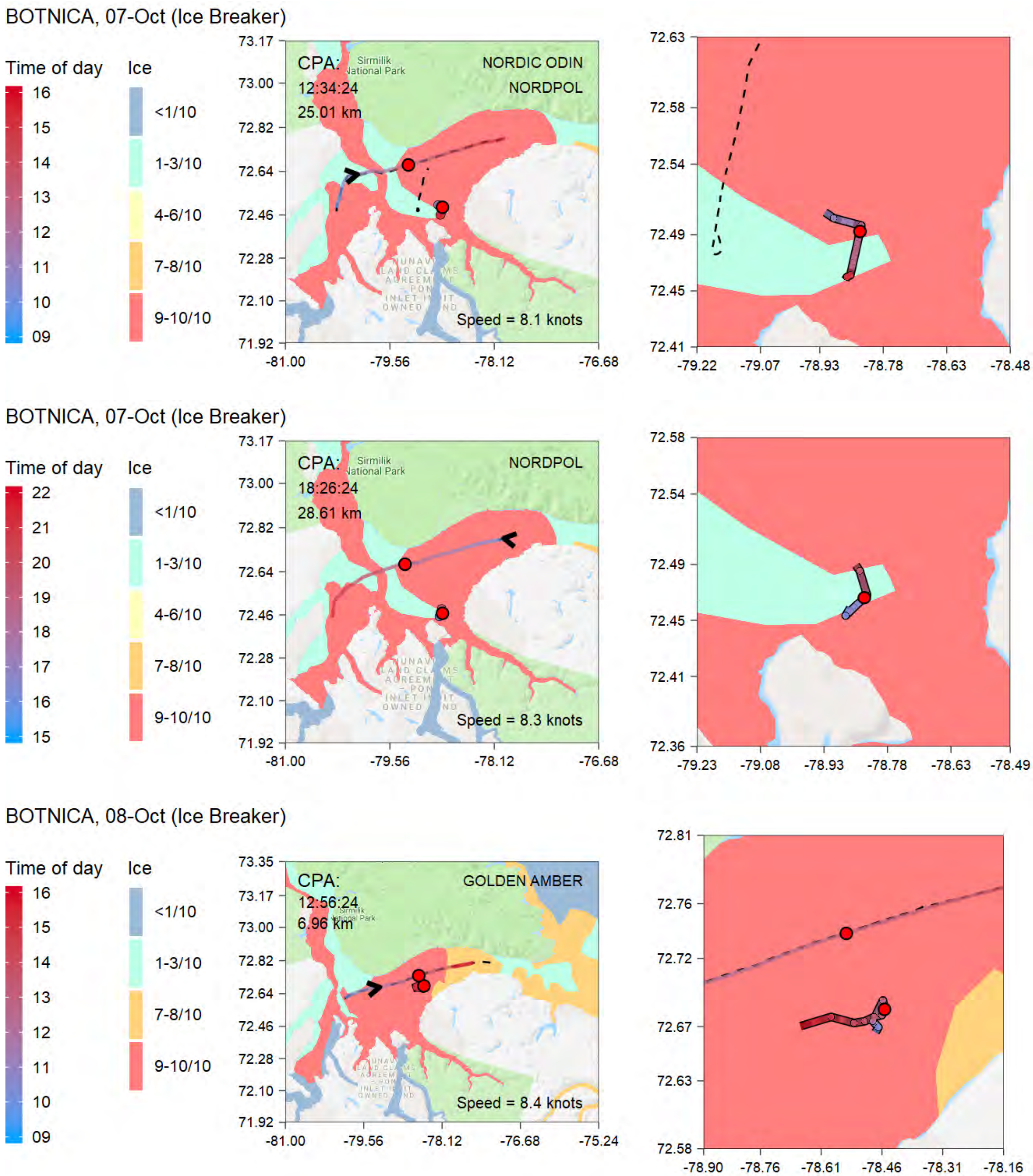

Figure 6: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 10 through 12). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

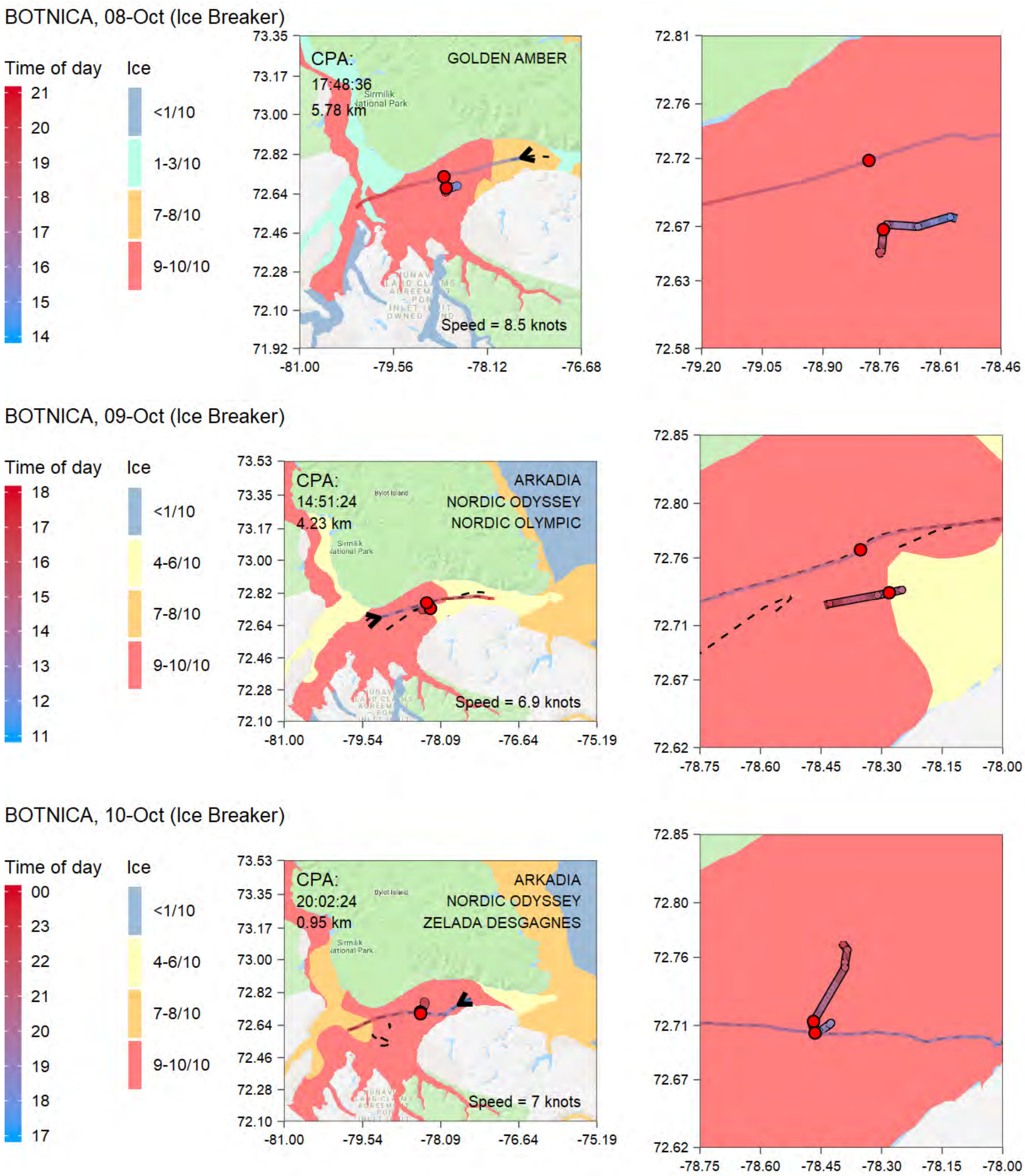

Figure 7: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 13 through 15). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

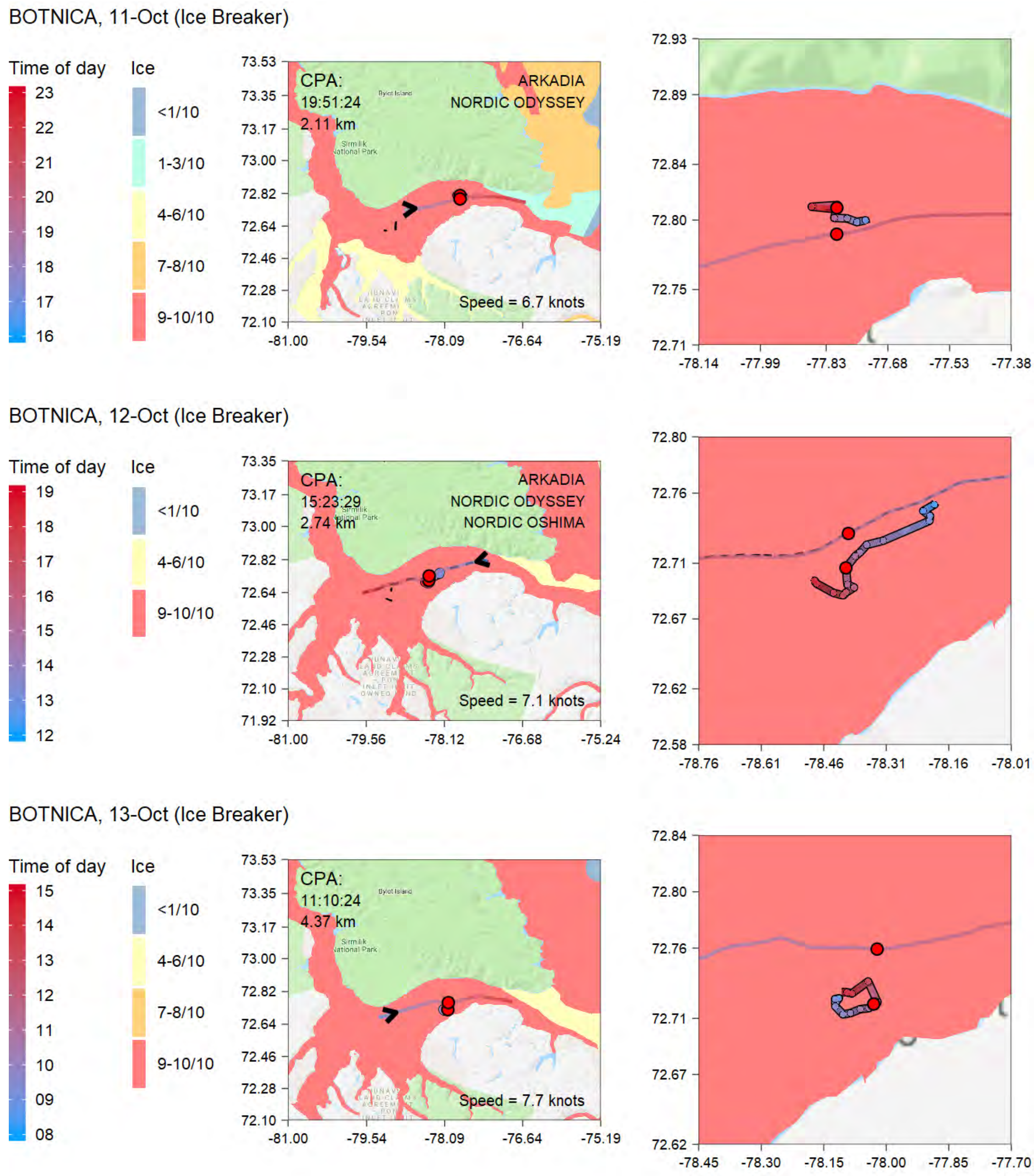

Figure 8: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 16 through 18). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

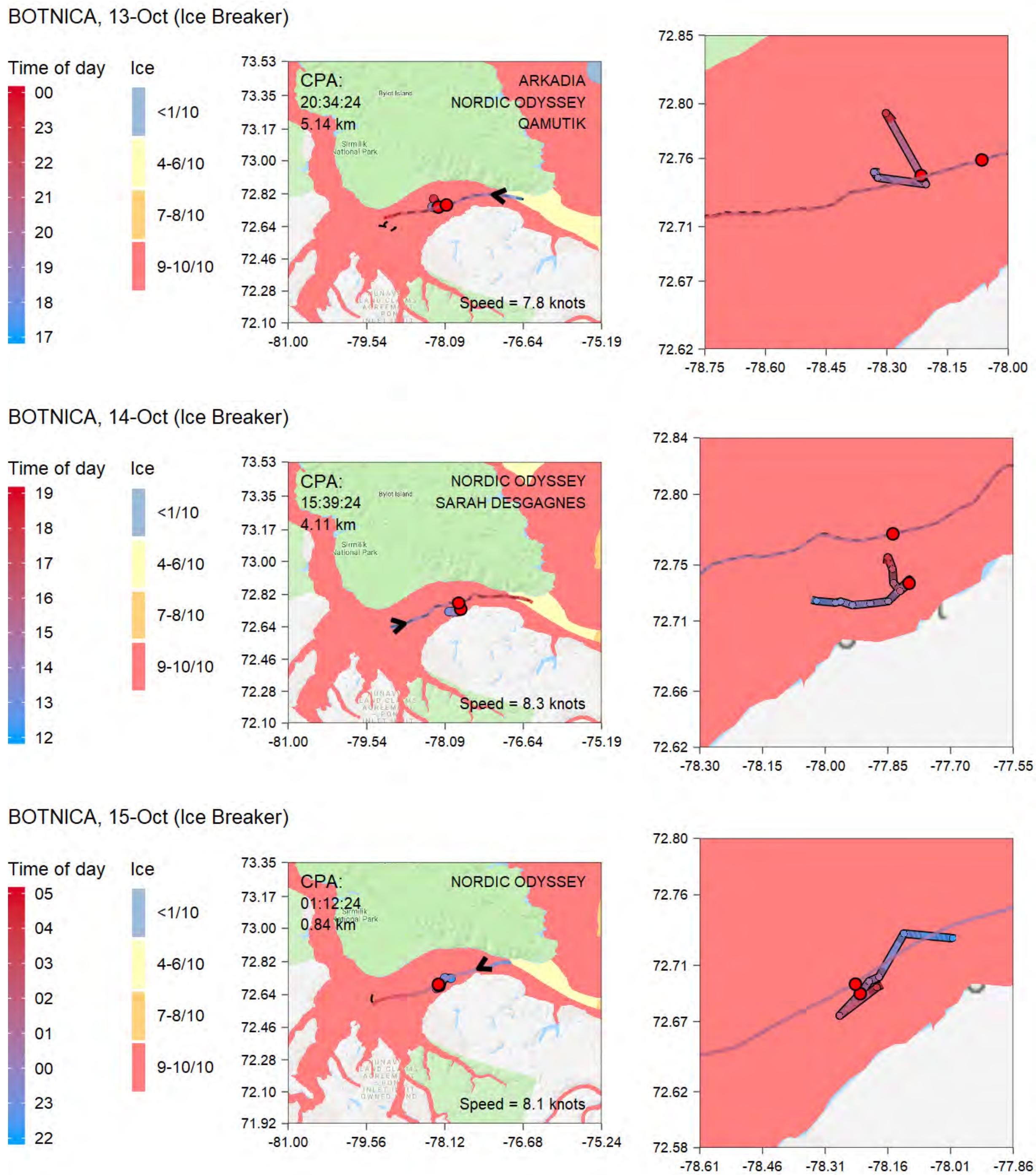

Figure 9: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 19 through 21). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

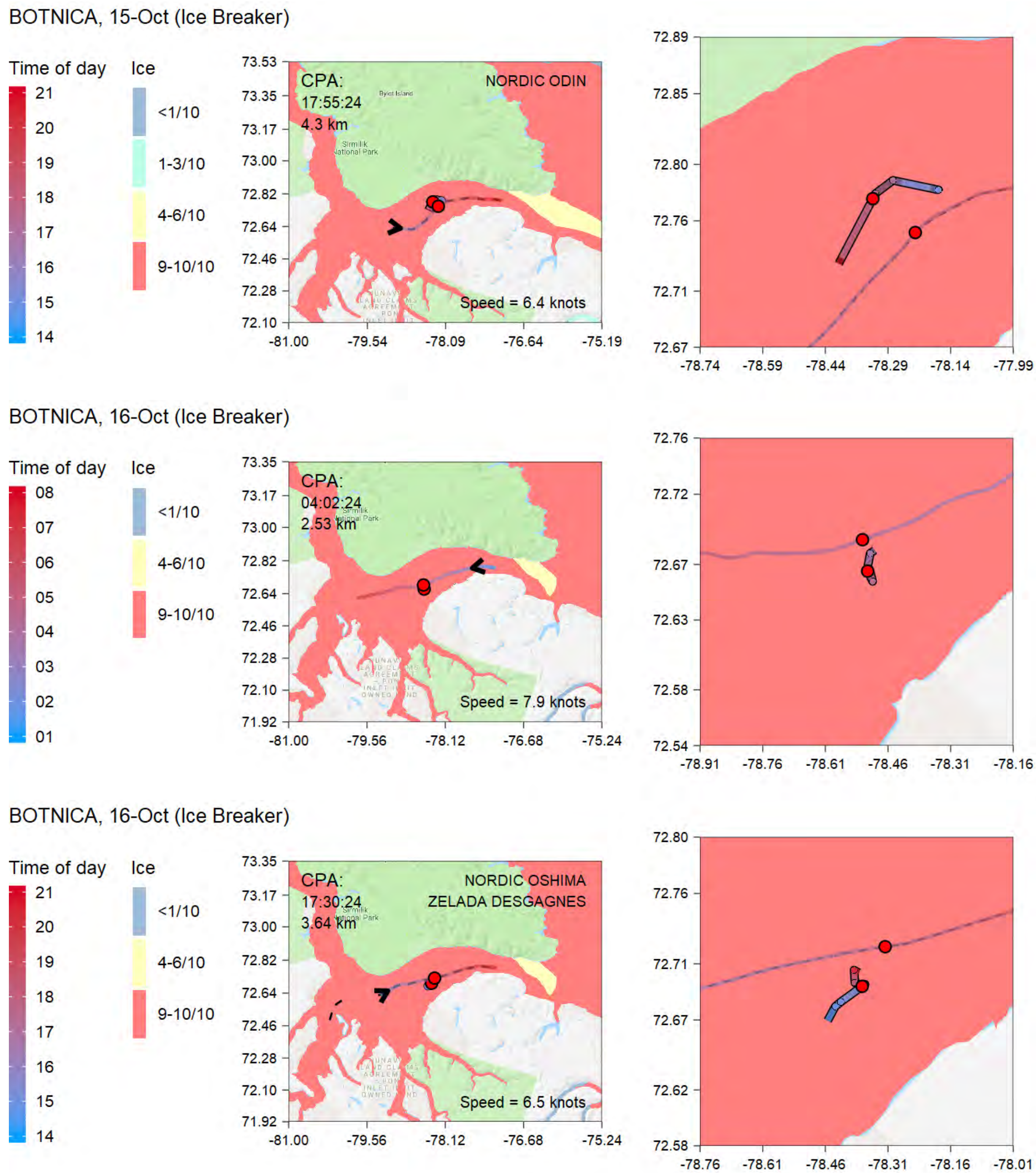

Figure 10: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 22 through 24). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

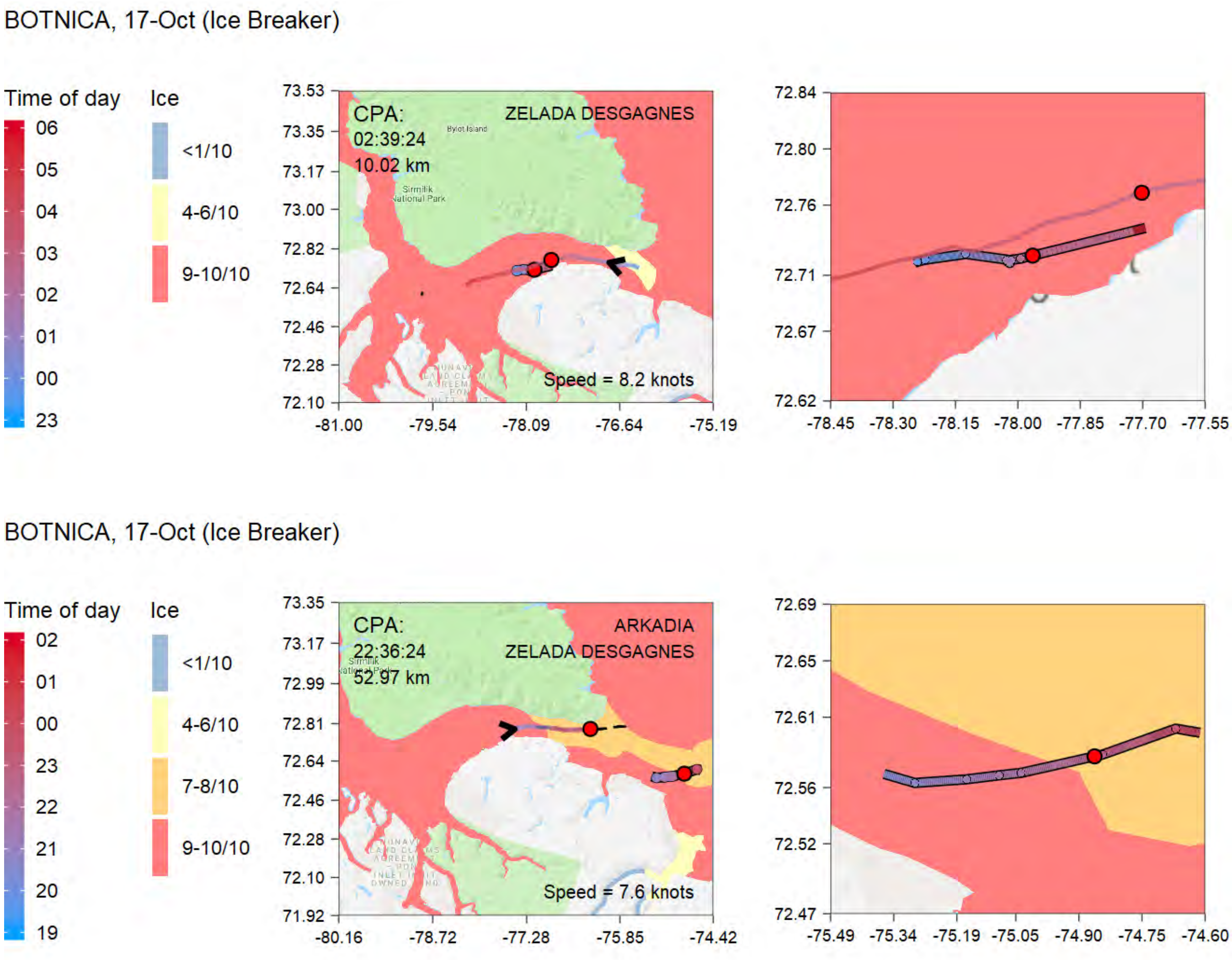

Figure 11: Closest point of approach (CPA) events of NW22 within 54.4 km of icebreaking operations and associated vessel traffic during the 2018 fall shoulder season (29 September - 17 October 2018; CPA events 25 and 26). The left panel shows the track of NW22 (thick line, color-coded for time) in relation to the icebreaker track (thin line, color-coded for time; average speed specified) and associated vessel tracks (black hatched lines; vessel names specified). The right panel is zoomed in to better illustrate the fine-scale movements of NW22. The CPA between NW22 and the icebreaking vessel is represented by a red dot on both the narwhal and the vessel tracks. Daily ice concentrations are also provided.

3.3 Percent Time in Disturbance and Avoidance Zones

Throughout the 19 day study period, NW22 remained within 54.4 km of a transiting icebreaker 47.4% of the time[4] (Figure 12), corresponding with the range associated with acoustic disturbance (i.e., 120 dB) based on acoustic modeling (Figure 12). During the same period, NW22 remained within 13.4 km of a transiting icebreaker 8.7% of the time[5], corresponding with the range associated with narwhal avoidance behaviour (i.e., 135 dB) as modeled for the same scenario (Richardson et al. 1995; Golder 2019a). NW22 interacted more closely with icebreaking operations toward the latter part of the fall shoulder season (Figure 13). Of note, NW22 became increasingly associated with transiting icebreakers and associated vessel traffic beginning on 08 October 2018, consistently spending approximately 12-24% of its total time within 13.4 km of the icebreaker which is the range associated with potential avoidance (i.e., 135 dB), as modeled by JASCO Applied Sciences (Quijano et al. 2019). Time reported within the modeled disturbance and avoidance zones is based on total data available within 100 km of the animal, as breaks in both the AIS and the GPS location data prevent analysis of the full extent of movements by NW22 in relation to transiting vessels.

[4] Based on available data within 100 km from whale.

[5] Based on available data within 100 km from whale.

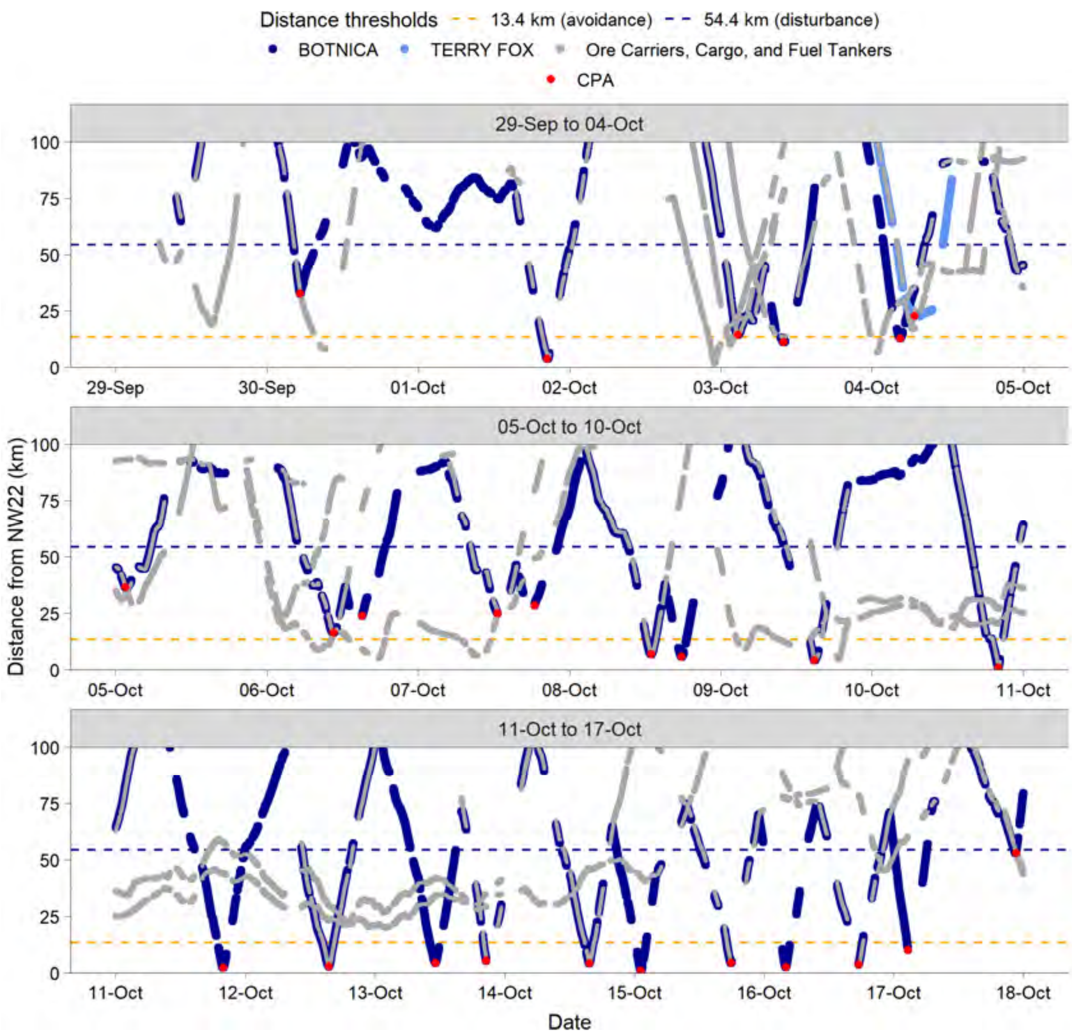

Figure 12: Distance (km) of NW22 from icebreaking operations and associated vessel traffic between 29 September – 17 October 2018. The 54.4 km distance associated with acoustic disturbance (i.e. 120 dB re: 1 μPa) is represented by the blue hatched line and the 13.4 km distance associated with avoidance (i.e. 135 dB re: 1 μPa) is represented by the orange hatched line.

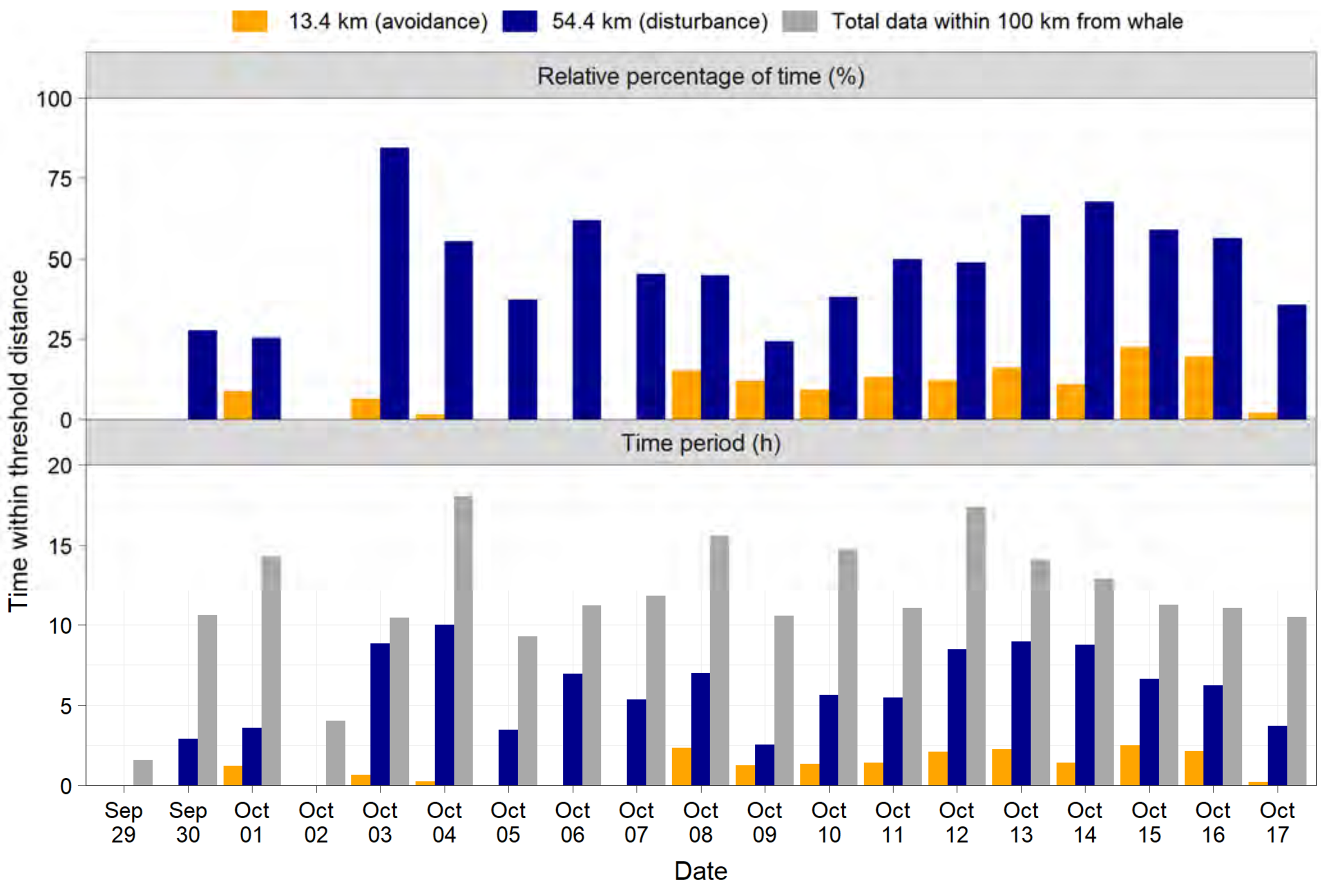

Figure 13: Relative percentage of time (%) that NW22 spent in the disturbance and avoidance zones of icebreaking operations (top plot). Number of hours that NW22 spent in the disturbance and avoidance zones of icebreaking operations, and total number of hours where data within 100 km from whale were available (bottom plot).

3.4 Distance and Time Since Crossing of NW22 over Vessel Tracks

NW22 made regular crossings to the bow and the stern of all vessel types during the 2018 fall shoulder season (Figure 14). However, NW22 did not cross behind the stern of icebreaking vessels or associated vessel traffic for a period of 4.5 hours following an active transit. This 4.5 h lag in entering a ship's sternward track was not evident in relation to any other vessel type when reviewing the track crossings of all narwhal tagged during the full extent of the 2017 and 2018 shipping seasons (Figure 15).

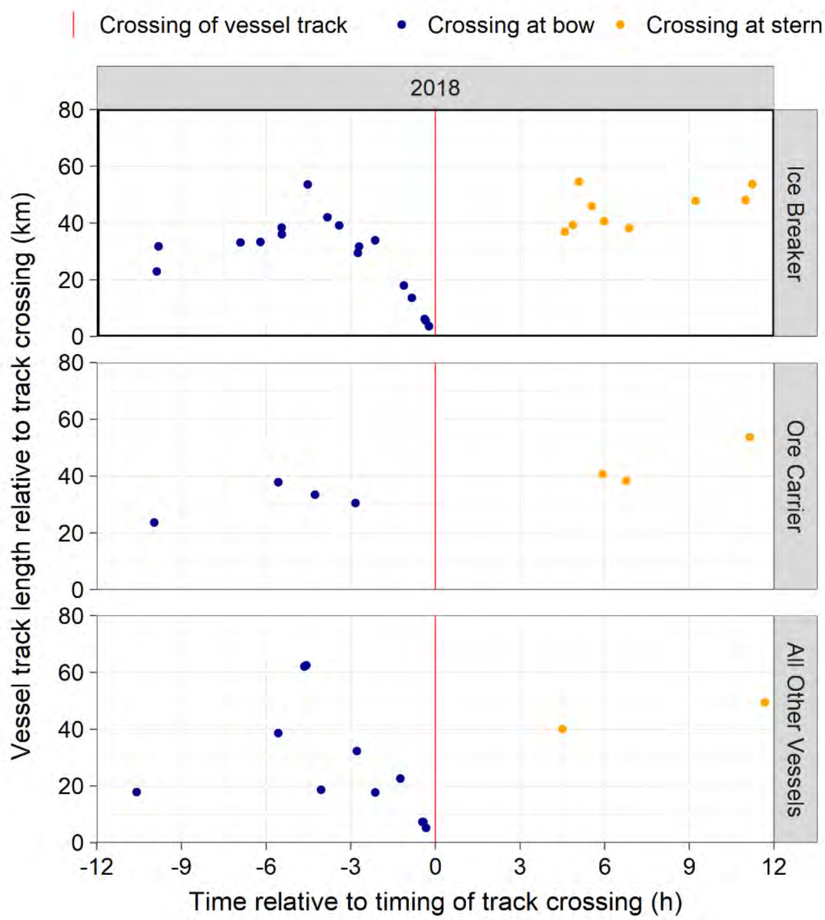

Figure 14: Distance (km) and time since crossing (h) of NW22 over vessel tracks during the 2018 fall shoulder season (29 September - 17 October 2018).

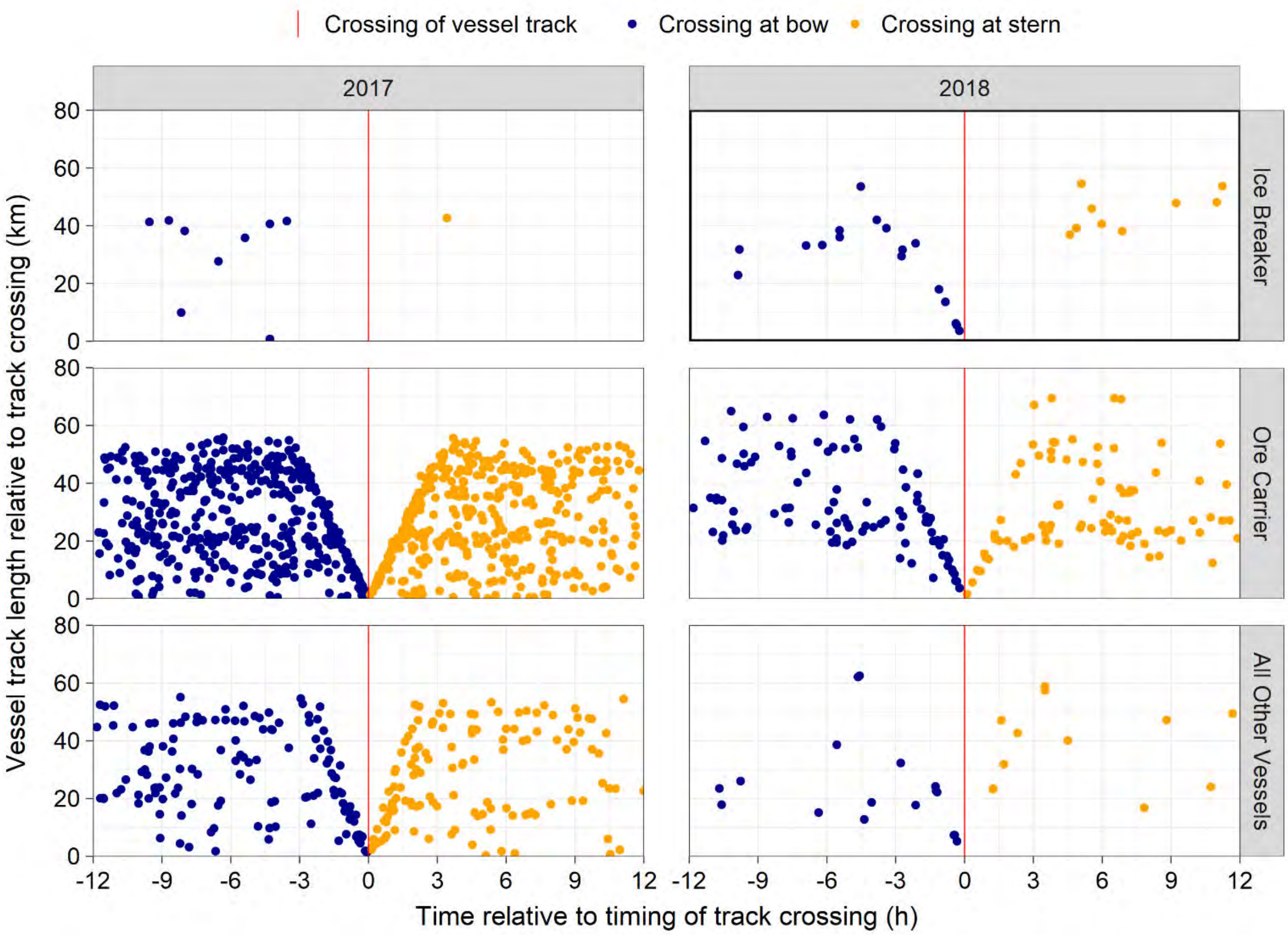

Figure 15: Distance (km) and time since crossing (h) over vessel tracks of all narwhal tagged during the full extent of the 2017 and 2018 shipping seasons.

4.0 DISCUSSION

Following is a high-level summary of key findings pertaining to narwhal behavioral responses to icebreaking operations and associated vessel traffic during the 2018 fall shoulder season based on the analysis of animal-borne tag data in relation to AIS ship-tracking data:

- Exposure to icebreaking operations and associated vessel traffic did not cause either NW21 or NW22 to be immediately displaced from the RSA during the 2018 fall shoulder season. Both animals remained in the vicinity of icebreaking operations for multiple days before the MSV *Botnica* departed the RSA on 21 October 2018. Of note, the tag associated with NW21 ceased transmitting location data on 08 October 2018, at which point it is not known whether the animal remained in the RSA or departed. NW22 departed the RSA on 17 October 2018, after spending 19 days in the vicinity of icebreaking operations.
- NW22 did not actively avoid icebreaking operations but rather appeared to interact more closely with the MSV *Botnica* and associated vessels as the 2018 fall shoulder season progressed. This finding may indicate possible habituation of the animal to icebreaking operations. It may also indicate that both the icebreaking vessel and animal were utilizing the path of least resistance (i.e. area with the least ice present) as the ice becomes increasingly dense later in the fall shoulder season. It is also possible that increasing ice concentration restricts movements by the animal, causing it to rely more heavily on the path created by icebreaking operations. However, this last scenario is not supported by the finding outlined in the following bullet point regarding narwhal use of vessel tracks. Further analysis is needed to adequately assess fine-scale movements of NW22 in relation to icebreaking operations and may be made available as part of the 2017/2018 integrated tag report, which will be released in Q1 of 2020.
- NW22 did not cross behind the stern of icebreaking vessels or associated vessel traffic for a period of 4.5 hours following an active transit. As sound generated from vessels in open water is known to radiate asymmetrically, with sound levels from the stern aspect typically being highest (Arveson and Vendittis 2000; McKenna et al. 2012), this finding may signify the animal's attempt to avoid the noisiest aspect of the vessel. However, the gap may also be due to data scarcity during the 2018 fall shoulder season (limited to one tagged animal). In addition, given the characteristics of sound that are generated from icebreaking operations and the way in which sound propagates under ice, the interpretation of the 4.5 h gap of crossing behind the stern of the vessel is not straightforward. Continued acoustic monitoring of Project-related icebreaking operations is therefore warranted to assess the sound levels radiated from the stern of individual vessels, including icebreakers.
- No obvious "freeze" response by narwhal to icebreaking operations as reported by Finley et al. (1990) was observed by NW22 during the 2018 fall shoulder season. However, it is acknowledged that brief, fine scale behavioral changes by narwhal may not be captured at the resolution provided by the animal-borne GPS tags.
- Distances selected to assess the time that NW22 resided within the zones associated with acoustic disturbance (i.e., 54.4 km) and avoidance (i.e., 13.4 km) of icebreaking operations and associated vessel traffic are based on the most conservative modeling scenarios presented by JASCO Applied Sciences (i.e., vessels transiting through 10/10 ice concentration, actively breaking ice; Quijano et al. 2019). It is evident from the daily satellite imagery, however, that ice conditions throughout the RSA were not 10/10 concentration for the full extent of the 2018 fall shoulder season (see Figures A-1 to A-19 in Appendix A).

Furthermore, a preliminary review of acoustic data collected during the 2019 spring shipping season in Eclipse Sound (Golder 2019b) suggests that estimated exposure periods incorporated into acoustic modeling were overly conservative by a factor of approximately two to three when compared to measured exposure periods for both disturbance and avoidance onset. Therefore, the percentage of time reported that NW22 was exposed to sound levels associated with disturbance (i.e., 120 dB re: 1 µPa 47.4% of the time) and avoidance (i.e., 135 dB re: 1 µPa 8.7% of the time) is likely an overestimate.

In summary, the narwhal-vessel interactions presented above suggest that Project-related icebreaking operations do not cause narwhal to be immediately displaced from the area, but that narwhal may actively avoid the sternward track of icebreaking vessels for a period of 4.5 hours. These results are based on a very limited dataset (a single animal over the course of 19 days), and further data collection and analysis is required to assess whether this trend is due to chance alone or whether it represents a real avoidance behaviour. NW22 interacted more closely with Project-related icebreaking operations as the 2018 fall shoulder season progressed and did not demonstrate any “freeze” response as reported by Finley et al. (1990). NW22 was exposed to sound levels associated with disturbance (i.e., 120 dB re: 1 µPa) for 47.4% of the fall shoulder season and to sound levels associated with avoidance (i.e., 135 dB re: 1 µPa) for 8.7% of the fall shoulder season, though a preliminary comparison of modeled vs. actual acoustic data collected during the 2019 spring shipping season (Golder 2019b) suggests that this is likely an overestimate. This technical memorandum presents the preliminary results of a more comprehensive analysis that will be made available as part of the 2017/2018 integrated tagging report. The integrated tagging report will be provided in draft form to the Marine Environmental Working Group in Q1 of 2020.

5.0 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional information, please contact the undersigned.

Golder Associates Ltd.

Ainsley Allen, MSc
Marine Biologist

Phil Rouget, MSc, RPBio
Senior Marine Biologist

Evan Jones, MASc, PEng
Associate

AA/PR/asd

Attachment 1: Daily Locations of Narwhal in relation to Vessel Traffic and Ice Conditions
(29 September - 17 October 2018)

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