Chapter 1
Assessment of Remaining Oil from the M/V *Selendang Ayu* Spill as of 2008

J. Michel, Z. Nixon, and M.G. Carls

Introduction

Background of the M/V *Selendang Ayu* Oil Spill

On 8 December 2004, the M/V *Selendang Ayu* ran aground and broke in half in rough seas off Unalaska Island, Alaska (53°38' N, 167°07' W). An estimated 354,218 gallons of oil (339,538 gallons of IFO 380 and 14,680 gallons of marine diesel and miscellaneous oils) were discharged.

Oil from the M/V *Selendang Ayu* incident impacted the coastline of Unalaska Island from Unalaska Bay to Konets Head, and beyond. Based on Shoreline Cleanup Assessment Team (SCAT) surveys, portions of approximately 112 kilometers (70 miles) of shoreline were identified as being in need of cleanup (Unified Command Shoreline Cleanup Summary Status, available at: http://www.dec.state.ak.us/spar/perp/response/sum_FY05/041207201/scat/scat_index.htm). The extent of shoreline surveys and the shoreline oiling using standard SCAT descriptors are illustrated in Figure 1.1. At the conclusion of the cleanup in June 2006, seven shoreline segments failed to reach final cleanup criteria (Unified Command Decision Memorandum, 23 June 2006). Other areas of potential concern were sites where alternative treatment methods were implemented, which potentially had residual subsurface oil, and heavily oiled areas in more protected locations where natural removal processes were likely slow.

Need for the Study

In 2005, 2006, and 2008, a mixed-function oxidase enzyme, cytochrome P4501A, was significantly induced in harlequin ducks within the spill area relative to those in a reference area[1]. The reference area in the harlequin duck study included Chernofski Harbor, which was a World War II military site that is listed under the Formerly Used Defense Sites Cleanup Program as "cleanup pending." Thus, Chernofski Harbor is classified as a historical human impacted site. The induction dichotomy between spill and reference areas suggests long-term exposure of harlequin ducks to residual oil, a pattern consistent with similar observations after the *Exxon Valdez* oil spill in Prince William Sound[2]. Induced mixed-function oxidase activity indicated potential source-oil bioavailability via exposure to contaminated media. The harlequin results demonstrated presence of bioavailable oil in the oiled areas impacted by the *Selendang Ayu*, and this study was initiated to further explore the extent of lingering oil in this environment and to evaluate potential exposure to other biota (e.g., mussels), providing data to inform trustee restoration decisions.

Study Objectives

The study objectives were to:

1. Determine the presence, distribution, and relative amount of oil remaining on beach segments of greatest concern to determine if Selendang Ayu oil remains on shorelines within the core spill area. Determination of the remaining oil distribution within a beach segment is important to identify future assessment needs and/or restoration options. The distribution and amount of oil in specific oiled zones (i.e., the oiled zones identified during previous SCAT surveys) was compared with the SCAT data from 2005 and/or 2006 to provide information on the relative changes over time and the effectiveness of natural removal processes at each location. Oil source was evaluated by comparing results from a petrogenic/pyrogenic index based on polynuclear aromatic hydrocarbon (PAH) composition.

2. Determine the weathering state of remaining oil to evaluate the potential toxicity of remaining oil. Understanding the chemical characteristics of any remaining oil and the rate of degradation are essential for determinations regarding further assessment, restoration, and scaling. A key component of any estimate of chronic injuries to nearshore biota is the anticipated length of time resources may be exposed to toxic oil. Chemical composition analysis of representative samples of the oil helped answer these questions; current composition of PAH and other oil constituents provided both an estimate of the weathering state of the oil (when compared to the original spilled oil) and of the potential chemical toxicity of the remaining oil.

3. Determine bioavailability of the remaining oil to assist in evaluating exposure and potential biological effects. Chemical analyses of blue mussels and passive samplers determined if oil was bioavailable and if continuing exposure could be detected[3, 4]. This effort was necessary to further assess chronic low-level exposure to biota. It complemented both the beach pit samples and the harlequin duck study – one of which represents a systematic, but macro-level search for oil on a given beach segment; the other reflecting the foraging habits of an obligate intertidal species.

Study Design Overview

Three distinct areas were sampled: the *Selendang Ayu* oil spill area, a reference area, and a human-impacted area. Beaches within the spill area were selected subjectively; segments included those that: 1) had not reached cleanup endpoint status and likely had persistent oil; 2) were subject to alternative treatment techniques during cleanup, such as berm relocation; 3) were near harlequin duck trap sites; and/or 4) were sites where subsistence samples showed evidence of oil exposure. These oiled segments were thus identified as being of greatest concern by the trustee agencies. Selected beach segments in the oiled area were located in Makushin Bay, Portage Bay, and Skan Bay (Fig. 1.2, Table 1.1). Unoiled reference beaches were located near and within Pumicestone Bay, a sizable nearby embayment with little known spill impact (Fig. 1.3, Table 1.1); note that although there were some very lightly oiled segments in Pumicestone Bay, the beach segments selected for study were documented as having no observable oil. Chernofski Harbor (Fig. 1.3, Table 1.1) was sampled because it was used in the duck study as a reference area, although it was classified in this environmental chemistry study as a human impact area because of its previous history.

Within segments, likely oiled zones were identified according to finer-scale measurements of oil distribution, oil loading, and substrate type derived from the SCAT data. This study was

designed to assess the presence, distribution, weathering state, and bioavailability of remaining surface and subsurface oil in the oiled zones within the identified segments.

The field data collection consisted of the following techniques:

1. Visual surveys of surface oil
2. Visual surveys of subsurface oil in excavated pits
3. Sampling of oiled sediments for chemical analysis
4. Deployment of passive sampler devices for chemical analysis
5. Collection of blue mussels (*Mytilus trossulus*) for chemical analysis

The passive sampler devices were deployed during Cruise 1 (28 June – 3 July 2008) and retrieved during Cruise 2, about one month later (24 July – 2 August 2008). All of the remaining data were collected during Cruise 2.

Report Overview

In the chapters that follow, methods, results, and discussion germane to the specific objectives are presented. Detailed site descriptions and visually detected oiling are the topics of Chapter 2 (Objective 1). These data provide an assessment of the presence, distribution, and relative amount of *Selendang Ayu* oil remaining on beach segments. Oil chemistry is the topic of Chapter 3 (Objectives 2 and 3); these mussel, sediment, and passive sampler data allow assessment of weathering, determination of hydrocarbon sources, measures of bioavailability, and allow estimation of potential biological effects. Although toxicity is a function of both concentration and hydrocarbon composition, only the latter was quantified, thus limiting our ability to predict lingering toxicity. Discussion of potential oil toxicity continues in Chapter 4 with exploration of theoretical scope for growth and lysosomal response in mussels collected early in 2008 (winter) and measured total PAH concentrations. All results are synthesized in Chapter 5.

ACKNOWLEDGEMENTS

This project was a cooperative study among the Trustees and the Responsible Party for the M/V *Selendang Ayu*. Many people contributed their time and knowledge during all aspects of the planning and conduct of the field work. Jenifer Kohout of the U.S. Fish and Wildlife Service was the project coordinator, and she is acknowledged for her support that greatly contributed to the success of the project. Others who assisted with the refinement of the study plan and review of the results include Jeep Rice, Norman Meade, Joel Reynolds, Philip Johnson, Paul Flint, Carol Fries, Amber Bethe, Mark Fink, Gayle Martin, Kim Trust, Erika Ammann, Jennifer Schorr, Dale Gardner, and Mark Curry.

We were ably assisted in the field work by Dale Gardner, Gay Harpole, Mac Oliver, Gary Mauseth, Andy Graham, Doug Reimer, Ion Cotsapas, and Scott Dungenberger.

References

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Table 1.1. List of sampled zones, oiled zone statistics, number of samples collected by type, and sampling dates. Type codes are: E – No Endpoint Attainment, A – Alternative Treatment, H – Harlequin Duck Sampling Site, S – Subsistence Sampling, NOO – No Oil Observed Segment.

Segment	Zone	Type	Oil Band Width (m)	Oil Band Buffered[1] Width (m)	Oil Zone Length (m)	Buffered Oil Zone Area (m^2)	1st Survey Date	2nd Survey Dates	Pits	Sediment Samples	Mussel Samples	Passive Arrays
HMP-05	B	H	2.5	6.5	60	390	6/30/08	7/28/08	10	3	2	2
HMP-05	C	H	3.5	7.5	160	1200	6/30/08	7/28/08	40	7	5	2
HMP-05	D	H	8	12	20	240	6/30/08	7/28/08	10	1	2	2
KPF-01	A	E	2	6	100	600	7/01/08	7/29/08	20	2	2	1
KPF-01	B	E	10	14	25	350	7/01/08	7/29/08	10	3	2	1
KPF-01	C	E	2	6	30	180	7/01/08	7/29/08	10	4	2	1
KPF-01	D	E	13	17	22	374	6/28/08	7/29/08	10	4	2	1
KPF-01	E	E	25	29	50	1450	6/28/08	7/29/08	40	8	2	1
KPF-01	F	E	3	7	150	1050	6/28/08	7/25/08	40	15	3	3
KPF-01	G	E	10	14	200	2800	6/28/08	7/25/08	80	16	3	2
MKS-14	A	E	15	19	100	1900	6/29/08	7/27/08	36	9	3	3
MKS-14	B	E	15	19	50	950	6/29/08	7/27/08	20	6	2	2
MKS-16	B/C	E	10	14	100	1400	6/29/08	7/27/08	45	12	3	3
MKS-16	F	E	4	8	50	400	6/29/08	7/27/08	10	2	3	1
PTN-03	A	H	2	6	400	2400	6/30/08	7/26/08	80	3	3	3
SKN-05	A	A	15	19	400	7600	6/30/08	7/31/08	80	11	1	3
SKN-11	A	S	5	9	30	270	7/01/08	7/24/08	10	1	2	1
SKN-15	B	E	5	9	30	270	7/01/08	7/30/08	10	3	2	1
SKN-15	C	E	4	8	25	200	7/01/08	7/30/08	10	5	4	2
SKN-15	D	E	15	19	60	1140	7/01/08	7/30/08	40	3	3	2
SKN-15	E	E	15	19	60	1140	7/01/08	7/30/08	40	10	3	2
SKS-04	A	S, A	1	5	235	1175	6/28/08	7/24/08	40	5	2	2
SKS-12	A	H, A	0.2	4.2	250	1050	6/28/08	7/24/08	33	3	3	3
PME-12	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	1	1
PME-13	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1
PME-13	2	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1
PME-14	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1

Table 1.1. Continued

Segment	Zone	Type	Oil Band Width	Oil Band Buffered[1] Width (m)	Oil Zone Length (m)	Buffered Oil Zone Area (m^2)	1st Survey Date	2nd Survey Dates	Pits	Sediment Samples	Mussel Samples	Passive Arrays
PME-15	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1
PME-15	2	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1
PME-18	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	2	1
PME-18	2	NOO	-	-	-	-	7/02/08	8/01/08	-	-	2	1
PMN-22	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	1	1
PMN-22	2	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1
PMS-13	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1
PMS-13	2	NOO	-	-	-	-	7/02/08	8/01/08	-	-	3	1
PMS-15	1	NOO	-	-	-	-	7/02/08	8/01/08	-	-	0	1
CFE-14	1	NOO	-	-	-	-	7/03/08	8/02/08	-	-	3	1
CFE-10	1	NOO	-	-	-	-	7/03/08	8/02/08	-	-	2	1
CFE-09	1	NOO	-	-	-	-	7/03/08	8/02/08	-	-	3	1
CFW-20	1	NOO	-	-	-	-	7/03/08	8/02/08	-	-	3	1
CFW-17	1	NOO	-	-	-	-	7/03/08	8/02/08	-	-	3	1
CFE-17	1	NOO	-	-	-	-	7/03/08	8/02/08	-	-	2	1
Totals									**724**	**136**	**105**	**63**

[1] The oiled band was buffered by 2 m each on the seaward and landward sides, to allow for minor inaccuracies in the zone dimensions and reoccupation process, as well as potential mobilization of oiled sediments landward or seaward of the oiled zones defined by the SCAT surveys.

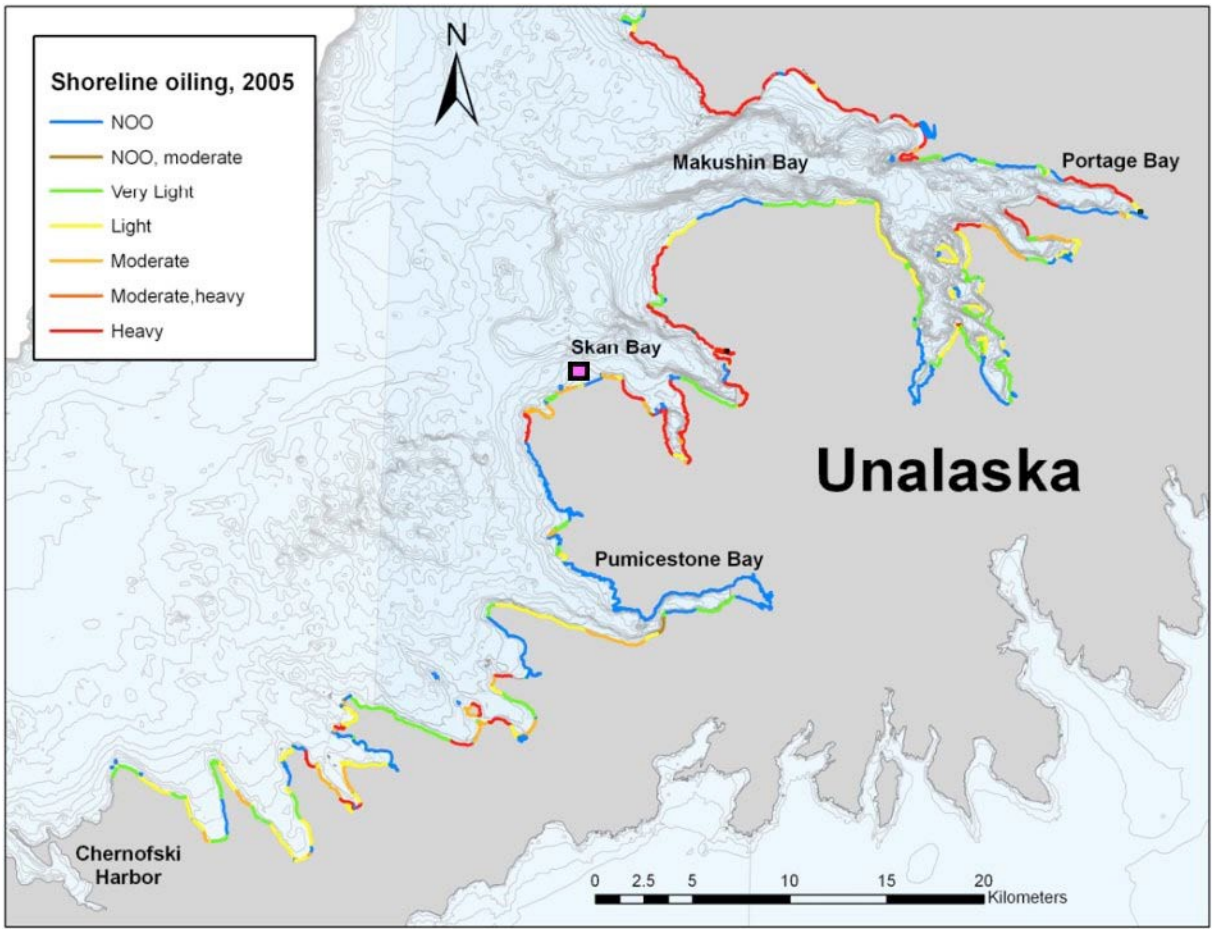

Figure 1.1. Shoreline oiling, 2005, in the *Selendang Ayu* spill area on Unalaska Island, Alaska. Assessment was completed with standard shoreline cleanup and assessment techniques (SCAT) and provides a frame of reference for the 2008 sampling program. Vessel grounding location shown as a purple square.

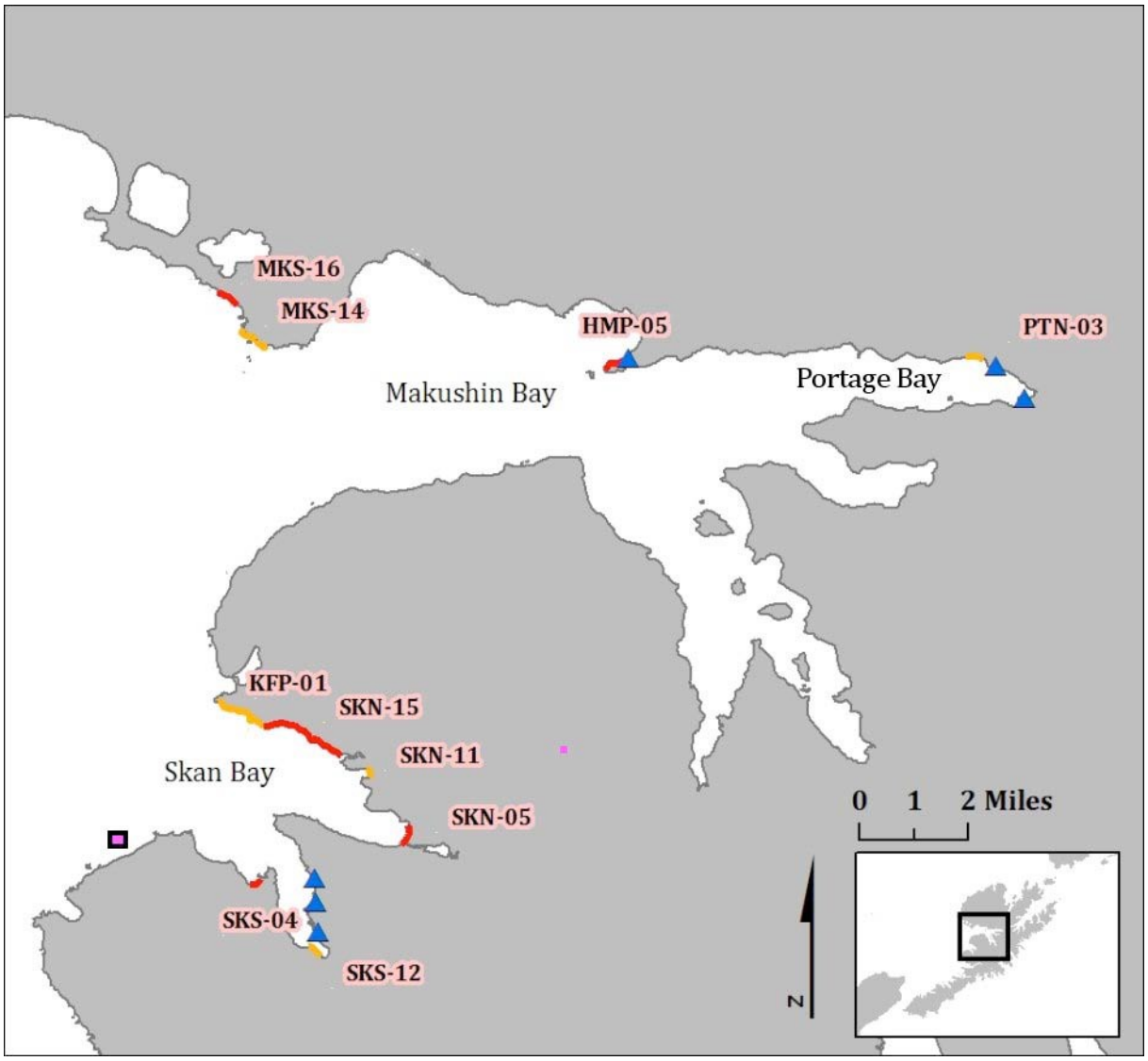

Figure 1.2. Map of priority oiled segments in core spill area. Segments depicted using alternating colors for clarity. Triangles indicate harlequin duck trap sites. Vessel grounding location shown as a purple square.

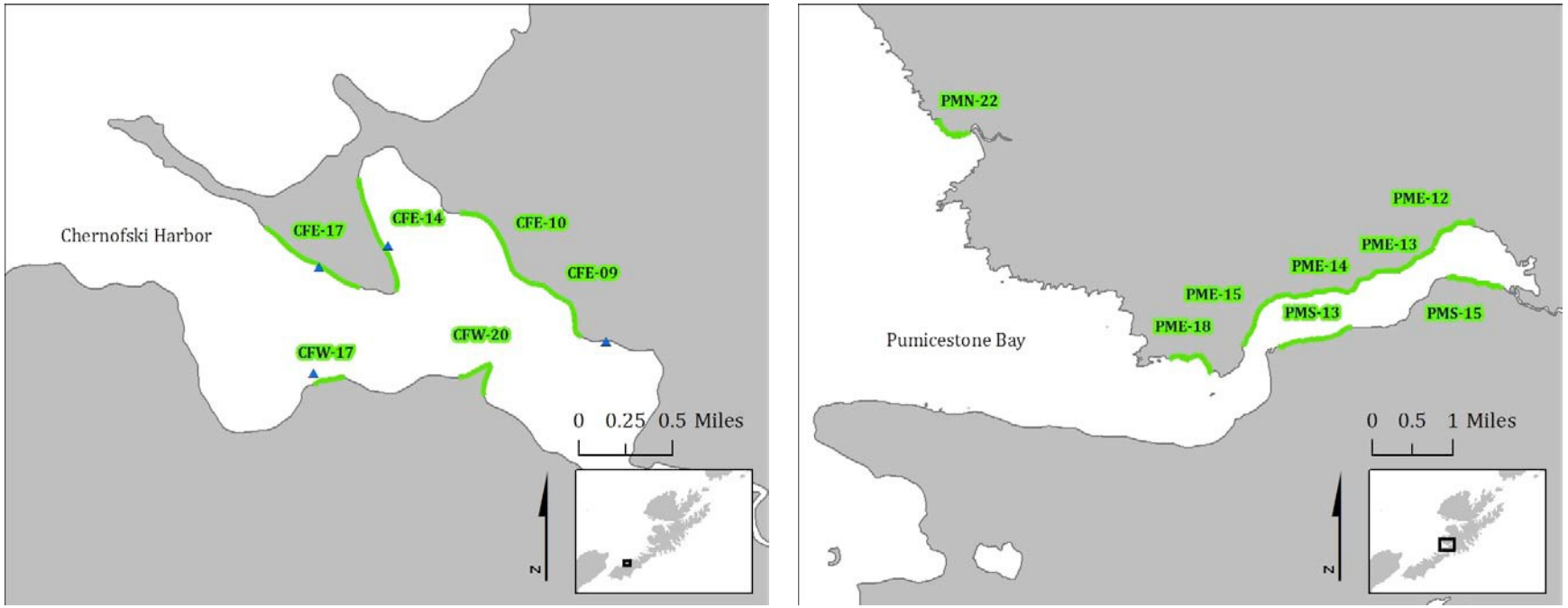

Figure 1.3. Maps of the comparison segments (no oil observed) in Chernofski Harbor and Pumicestone Bay. Segments depicted in green. Blue triangles indicate harlequin duck trap sites.