Anna Barford
Canada Shipping Campaigner
STAND Environmental Society
[redacted]

April 12, 2023

The Honourable Steven Guilbeault
Minister of Environment and Climate Change
Fontaine Building 12th floor
200 Sacré-Coeur Blvd
Gatineau QC K1A 0H3
Email: ministre-minister@ec.gc.ca

Dear Minister Guilbeault:

Re: Enforcement of *Fisheries Act*, s. 36(3) to Prevent Pollution from Shipping Sector

We write to you in your capacity as the Government of Canada's Minister responsible for enforcement of subsection 36(3) of the *Fisheries Act*, RSC 1985, c F-14, to request information on actions your Department is taking to enforce this statutory provision and prevent pollution of the marine environment by the shipping sector in the coastal waters of Canada, particularly cruise ships operating along the Pacific coast.

Specifically, we request the following information:

1. The number of investigations initiated against cruise ship operators between January 1, 2018 and December 31, 2022 in respect of compliance with s. 36(3);

2. The number of prosecutions initiated against cruise ship operators between January 1, 2018 and December 31, 2022 in respect of breaches of s. 36(3);

3. Particulars of any penalties imposed against cruise ship operators between January 1, 2018 and December 31, 2022 for contraventions of s. 36(3);

4. The number of applications the Department of Environment and Climate Change received between January 1, 2018 and December 31, 2022 to authorize cruise ship operators to discharge deleterious substances, pursuant to s. 36(4) and the *Wastewater Systems Effluent Regulations*, SOR/2012-139, and the particulars of these applications;

5. The number of applications the Department of Environment and Climate Change approved between January 1, 2018 and December 31, 2022 authorizing cruise

ship operators to discharge deleterious substances, pursuant to s. 36(4) and the *Wastewater Systems Effluent Regulations*, SOR/2012-139, and the particulars of these applications;

6. Particulars of any investigations, contraventions or penalties regarding the performance, monitoring or reporting of Exhaust Gas Cleaning Systems ("EGCSs") in cruise ships operating along the Pacific coast of Canada between January 1, 2018 and December 31, 2022; and

7. Any rationale for non-enforcement of subsection 36(3) of the *Fisheries Act* against cruise ship operators.

As stated below, we are considering pursuing a remedy under Article 24.4 of Chapter 24 of the *United States-Mexico-Canada Agreement* (2020) (the "*USMCA*") in respect of s. 36(3) of the *Fisheries Act*.[1] We therefore request a timely response to the questions outlined above, to allow us to properly evaluate our options.

A. Canada's Fisheries Act and Unlawful Pollution of the Marine Environment

As you are aware, under Canada's *Fisheries Act*, RSC 1985, c F-14 it is unlawful for any person to deposit or permit the deposit of any type of deleterious substance into water frequented by fish, except as authorized by regulations enacted by the Government of Canada.

This prohibition is provided for at subsection 36(3) and aligns with the express purpose of the legislation of providing a framework for "the conservation and protection of fish and fish habitat, including by preventing pollution" (s. 2.1):

> **Deposit of deleterious substance prohibited**
>
> 36 (3) Subject to subsection (4), no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter any such water.

The *Fisheries Act* applies to all waters in the territorial sea of Canada, all internal waters of Canada, and, with respect to a sedentary species, any portion of the continental shelf of Canada that is beyond the limits of Canadian fisheries waters (s. 2.2).

The legislation provides a limited exemption for polluting fish-bearing waters, stating that a person does not contravene s. 36(3) by depositing or permitting the deposit of a waste, pollutant or deleterious substance under conditions authorized by regulations (s. 36(4)):

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[1] *Agreement between the United States of America, the United Mexican States, and Canada* (the "*USMCA*"), effective July 1, 2020.

Deposits authorized by regulation

36 (4) No person contravenes subsection (3) by depositing or permitting the deposit in any water or place of

(a) waste or pollutant of a type, in a quantity and under conditions authorized by regulations applicable to that water or place made by the Governor in Council under any Act other than this Act;

(b) a deleterious substance of a class and under conditions — which may include conditions with respect to quantity or concentration — authorized under regulations made under subsection (5) applicable to that water or place or to any work or undertaking or class of works or undertakings; or

(c) a deleterious substance the deposit of which is authorized by regulations made under subsection (5.2) and that is deposited in accordance with those regulations.

The Government of Canada is authorized to make regulations prescribing:

- the deleterious substances or classes thereof authorized to be deposited;
- the waters or places or classes thereof where any deleterious substances are authorized to be deposited;
- quantities or concentrations of any deleterious substances that are authorized to be deposited;
- the conditions or circumstances under which any deleterious are authorized to be deposited; and
- the persons who may authorize the deposit of any deleterious substances in the absence of any other authority. (s. 36(5))

A deleterious substance is defined at s. 34(1) as:

(a) any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, or

(b) any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water.

Order in Council PC 2014-196 (enacted by the Governor General in Council in 2014 pursuant to s. 43.2 of the *Fisheries Act*) designates the Minister of Environment as Canada's minister responsible for administration and enforcement of s. 36(3).[2]

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[2] PC 2014-196, February 28, 2014, enacting Order S1/2014—21 "Order Designating the Minister of the Environment as the Minister Responsible for the Administration and Enforcement of Subsections 36(3) to (6) of the Fisheries Act", s. 2.

Where the deposit of a deleterious substance has been authorized by regulation, the Minister may require any person so authorized to conduct sampling, analyses, tests, measurements or monitoring, to install or operate equipment or comply with any procedures, and to report any information necessary for the Minister to verify whether the person is depositing the deleterious substance in the manner authorized. (s. 36(5.5)).

The *Fisheries Act* contains strong enforcement provisions (at s. 38), authorizing the Minister to designate inspectors and authorizing inspectors to "enter any place or premises, including a vehicle or vessel — other than a private dwelling-place" — in which the inspector believes on reasonable grounds that:

(a) there is anything that is detrimental to fish habitat; or
(b) there has been carried on, is being carried on or is likely to be carried on any work, undertaking or activity resulting or likely to result in
  - (i) the death of fish,
  - (i.1) the harmful alteration, disruption or destruction of fish habitat, or
  - (ii) the deposit of a substance in water frequented by fish or in any place under any conditions where the substance or any other substance that results from the deposit of the substance may enter any such water.

If a deleterious substance is deposited into water frequented by fish in a manner contrary to the act, any person who owns or has charge, management or control of the substance (or the work, undertaking or activity that resulted in the deposit, or who causes the substance to be deposited into the water) has a duty to notify without delay an inspector, fishery officer, fishery guardian or authority prescribed by the regulations (s. 38(5)). A person bound by this duty also has a duty to take corrective measures, meaning they must, as soon as feasible, take all reasonable measures to prevent the occurrence or "to counteract, mitigate or remedy any adverse effects that result from the occurrence or might reasonably be expected to result from it." (s. 38(6)).

When making decisions in respect of enforcement of the anti-pollution provision at s. 36(3) and other provisions, the Minister may consider several factors, including:

a. the application of a precautionary approach and an ecosystem approach;
b. scientific information;
c. Indigenous knowledge of the Indigenous peoples of Canada that has been provided to the Minister;
d. community knowledge; and
e. social, economic and cultural factors in the management of fisheries (s. 2.5 (a), (c), (d), (e), (f), (g)).[3]

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[33] Fisheries Act, RSC 1985, c F-14, s. 2.5; Order S1/2014—21 "Order Designating the Minister of the Environment as the Minister Responsible for the Administration and Enforcement of Subsections 36(3) to (6) of the Fisheries Act", s. 3.

Every person who contravenes s. 36(3) is guilty of an offence and liable on conviction by way of indictment of a fine of between $15,000 and $1,000,000 (for a first offence) and a fine of between $30,000 and $2,000,000 or imprisonment of up to 3 years (or both) for a second and any subsequent offence. A corporation convicted by way of indictment is liable for a fine of between $500,000 and $6,000,000 (for a first offence) and between $1,000,000 and $12,000,000 for a second and any subsequent offence (s. 40(2)(a)).

If the Crown proceeds by way of summary conviction a person is liable to a fine of between $5,000 and $3000,000 (for a first offence) and a fine of between $10,000 and $600,000 or imprisonment of up to 6 months (or both) for a second and any subsequent offence. A corporation convicted by way of summary conviction is liable for a fine of between $100,000 and $4,000,000 (for a first offence) and between $200,000 and $8,000,000 for a second and any subsequent offence (s. 40(2)(b)).

The jurisdiction of the courts of Canada to enforce the anti-pollution provisions of the *Fisheries Act* against vessels, their owners and their crew — including against foreign vessels, owners and crew, even when lying off the coast of Canada — is expressly provided for at s. 88 of the *Fisheries Act* and ss. 257-258 of the *Canada Shipping Act*, SC 2001, c 26.

Regulations governing the discharge of deleterious substances in wastewater are established in the *Wastewater Systems Effluent Regulations*, SOR/2012-139, including an application procedure for authorizing discharges pursuant to s. 36(4) of the *Fisheries Act* (s. 25(1)).

B. Canada's International Obligations to Protect the Marine Environment from Cruise Ship Pollution

A number of international instruments support the principles that Canada should not pollute the marine environment.

These include the *United States-Mexico-Canada Agreement* (2020) (the "*USMCA*", successor to the *NAFTA* treaty), the *International Convention for the Prevention of Pollution from Ships* (the "MARPOL" treaty", 1973), and *the Convention on Biological Diversity* (1992).

Duty to Protect the Marine Environment from Ship Pollution

Canada has an express duty under Article 24.10(1) of the *USMCA* "to prevent the pollution of the marine environment from ships."[4]

This duty flows from its obligations under the International Convention for the Prevention of Pollution from Ships (1973), as amended by the Protocols of 1978 and

[4] *USMCA*, ch. 24, art. 24.10(1).

1997 (the "MARPOL Convention"), to which Canada is a signatory. A number of Annexes to MARPOL clarify the obligations of parties (with amendments from time to time to respond to new technical information or emerging issues), including obligations to enact and enforce regulations to prevent pollution of the marine environment.[5]

The standard that Canada must meet in fulfilling this duty under MARPOL is defined in the *USMCA* Art 24.10, footnote 14:

> A Party shall be deemed in compliance with this provision if it maintains the measure or measures listed in Annex 24-B implementing its obligations under MARPOL Convention, or adopts any subsequent measure or measures that provide an equivalent or higher level of environmental protection as the measure or measures listed.[6]

Annex 24-B of Chapter 24 states that the applicable measure for Canada is the *Canada Shipping Act*, 2001 and its related regulations.[7]

Related to its duty to prevent marine pollution from ships, Canada has a duty to cooperate with the United States and Mexico to address matters of mutual interest with respect to pollution of the marine environment, including:

- Pollution from routine operations of ships;
- Deliberate pollution from ships;
- Development of technologies to minimize ship-generated waste; and
- Emissions from ships;
- Increased protection in special geographic areas;
- Enforcement measures including notifications to Flag stages and, as appropriate, to port States.[8]

Duty to Enforce Its Own Environmental Laws and Investigate Complaints Under the USMCA

Canada has a duty under the *USMCA* to "adopt, maintain, and implement laws, regulations, and all other measures necessary to fulfill its respective obligations under" the International Convention for the Prevention of Pollution from Ships, 1973, as amended by the Protocol of 1978 (s. 24.8(4)).[9]

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[5] The particulars of this international instruments are described in Chapter 24, art. 24.10(1), footnote 13 as: "the International Convention for the Prevention of Pollution from Ships, done at London, November 2, 1973, as modified by the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, done at London, February 17, 1978, and the Protocol of 1997 to Amend the International Convention for the Prevention of Pollution from Ships, 1973 as Modified by the Protocol of 1978 relating thereto, done at London, September 26, 1997 (MARPOL Convention), and any existing and future amendments to the MARPOL Convention, to which the Parties are parties."
[6] *USMCA*, ch. 24, art. 24.10, footnote 14.
[7] *USMCA*, ch. 24, Annex 24-B.
[8] *USMCA*, ch. 24, art. 24.10(3).
[9] *USMCA*, ch. 24, art. 24.8(4).

Canada also has a duty under the *USMCA* to ensure that "an interested person may request that the Party's competent authorities investigate alleged violations of its environmental laws, and that the competent authorities give those requests due consideration, in accordance with its law."[10]

Canada also has a duty under Article 24.5(2) of the *USMCA* to "provide for the receipt and consideration of written questions or comments from persons … regarding its implementation of this Chapter," and to "respond in a timely manner to these questions or comments in writing and in accordance with domestic procedures, and make the questions or comments and the responses available to the public, for example by posting on an appropriate public website."[11]

Canada also has a duty to "make use of existing, or establish new, consultative mechanisms, for example national advisory committees, to seek views on matters related to the implementation of this Chapter. These mechanisms may include persons with relevant experience, as appropriate, including experience in business, natural resource conservation and management, or other environmental matters."[12]

Duty to Promote Conservation of Biological Diversity

Canada has a duty under Article 24.15 of the *USMCA* to "promote and encourage the conservation and sustainable use of biological diversity, in accordance with its law or policy." [13] This includes recognition of "the importance of respecting, preserving, and maintaining knowledge and practices of indigenous peoples and local communities embodying traditional lifestyles that contribute to the conservation and sustainable use of biological diversity."[14] The duty to promote conservation of biological diversity also includes recognition of "the importance of public participation and consultation … in the development and implementation of measures concerning the conservation and sustainable use of biological diversity," and cooperation to exchange information and experiences related to "the protection and maintenance of ecosystems and ecosystem services."[15]

Canada's duties in the *USMCA* regarding conservation of biological diversity are consistent with Canada's obligations in the *Convention on Biological Diversity*, made in 1992. That convention defines "biological diversity" at Article 2 as meaning: "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems."[16] Canada and other contracting parties have pledged to: "Develop national strategies,

[10] *USMCA*, ch. 24, art. 24.6(1).
[11] *USMCA*, ch. 24, art. 24.5(2).
[12] *USMCA*, ch. 24, art. 24.5(3).
[13] *USMCA*, ch. 24, art. 24.15(2).
[14] *USMCA*, ch. 24, art. 24.15(3).
[15] *USMCA*, ch. 24, art. 24.15(5) and (6).
[16] *Convention on Biological Diversity* (1992), art. 2.

plans or programmes for the conservation and sustainable use of biological diversity" and to "Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies" (art. 6).[17]

Duty to Conserve Fisheries and Protect Wild Fish Species

Canada has recognized in Article 24.17 of the *USMCA* the "importance of taking measures aimed at the conservation … of fisheries."[18]

Canada has also committed at Article 24.18 to operate a fisheries management system that is designed to "protect marine habitat", and which is based "on the best scientific evidence available and on internationally recognized best practices for fisheries management and conservation."[19]

International instruments that are applicable to the exercise of this duty include:

(a) the United Nations Convention on Law of the Sea (UNCLOS), done at Montego Bay, December 10, 1982;
(b) the United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, done at New York, December 4, 1995 (UN Fish Stocks Agreement);
(c) the FAO Code of Conduct for Responsible Fisheries;
(d) the 1993 FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (Compliance Agreement), done at Rome, November 24, 1993;
(e) the 2001 FAO International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing (IUU IPOA), adopted at Rome, February 23, 2001;
(f) and the 2009 Agreement on Port State Measures to Prevent, Deter, and Eliminate IUU Fishing (Port State Measures Agreement), done at Rome, November 22, 2009.[20]

Duty to Conserve Marine Species including Marine Mammals

Canada has a duty under Article 24.19 of the *USMCA* to promote the long-term conservation of marine mammals and other marine species through "the implementation and effective enforcement of conservation and management measures."[21]

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[17] *Convention on Biological Diversity* (1992), art. 2.
[18] *USMCA*, ch. 24, art. 24.17(2).
[19] *USMCA*, ch. 24, art. 24.18(1) and (3).
[20] *USMCA*, ch. 24, art. 24.18(3), footnote 19.
[21] *USMCA*, ch. 24, art. 24.19(1).

Duty to Not Pollute under the Boundary Waters Treaty

In addition to these duties enumerated under the *USMCA* and *AEC*, Canada has a duty to prevent pollution "to the injury of health or property" along the "boundary waters" of Canada and the United States pursuant to the *Boundary Waters Treaty* of 1909.

The *Treaty Between the United States and Great Britain Relating to Boundary Waters and Questions Arising Between the United States and Canada, 1909* (the "*Boundary Waters Treaty, 1909*") states at the Article IV that:

> "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other."

Article VII of the *Boundary Waters Treaty* established the International Joint Commission, a 6-member binational entity which has worked to resolve more than 100 matters raised by the respective federal governments since its formation in 1912.[22]

C. Canada's International and Domestic Obligations to Protect the Marine Environment from Ship Pollution under the Canada Shipping Act, 2001

As stated above, Canada has agreed in Chapter 24 of the *USMCA* to implement its MARPOL obligations in respect of marine pollution from ships through the *Canada Shipping Act, 2001*, SC 2001, c 26 (the "*Shipping Act*") and regulations.

The *Shipping Act* includes the objectives to "protect the marine environment from damage due to navigation and shipping activities" and "establish an effective inspection and enforcement program."[23]

The Act applies to "Canadian vessels everywhere and … foreign vessels in Canadian waters", and anti-pollution regulations made under paragraph 35(1)(d) also apply (if they so state) to "foreign vessels in waters in the exclusive economic zone of Canada."[24]

The Exclusive Economic Zone of Canada is defined (pursuant to s. 35 of the *Interpretation Act*, RSC 1985, c I-21 and s. 13(1) of the *Oceans Act*, SC 1996, c 31) as an area of sea extending 200 nautical miles outward from Canada's territorial sea (which is itself defined as a belt of sea extending 12 nautical miles outward from the low-water line along the coast).[25]

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[22] International Joint Commission, "The Boundary Waters Treaty of 1909" < https://www.ijc.org/en/boundary-waters-treaty-1909 >.
[23] *Canada Shipping Act, 2001*, SC 2001, c 26, s. 6.
[24] *Canada Shipping Act, 2001*, SC 2001, c 26, s. 8.
[25] *Interpretation Act*, RSC 1985, c I-21, s. 35; *Oceans Act*, SC 1996, c 31, ss. 4 and 13(1).

Section 35(1)(d) of the *Shipping Act* authorizes the Government of Canada (through the Governor in Council, on recommendation of the Minister of Transport) to make regulations implementing anti-pollution measures of MARPOL and other treaties, including “establishing stricter standards than [the international instrument] sets out.” A person or vessel who contravenes one of these regulations is liable on summary conviction to a fine of up to $1,000,000 or to imprisonment for up to 18 months, or both (s. 38(1)).[26]

The *Shipping Act* also authorizes (at s. 35.1(1)) the Government of Canada (through the Governor in Council, on recommendation of the Minister of Transport) to make regulations for “the protection of the marine environment from the impacts of navigation and shipping activities”, including regulations respecting “the design, construction, manufacture and maintenance of vessels” (a), “inspections and testing of vessels” (g), and “the development, maintenance and implementation of a management system that sets out the manner in which marine environment protection measures are to be integrated into day-to-day navigation and shipping operation” (i).

Section 187 of the *Shipping Act* prohibits any person or vessel from discharging a “prescribed pollutant”, except in accordance with regulations made under this part or a permit granted under *Canadian Environmental Protection Act*, 1999, Part 7. The Governor in Council is authorized at s. 190(1) of the *Shipping Act* to make regulations “prescribing pollutants … and respecting the circumstances in which such pollutants may be discharged”.

Any person or vessel that discharges a pollutant in contravention of section 187 is guilty of an offence punishable by a fine of up to $1,000,000 or up to 18 months imprisonment upon summary conviction (s. 191(1) and (2)). If an offence is committed or continued on more than one day, the person or vessel is liable to be convicted for a separate offence for each day on which it is committed or continued (s. 191(3)).

In determining an appropriate punishment, the court may consider the following factors:

a. the harm or risk of harm caused by the offence;
b. an estimate of the total costs of clean-up, of harm caused, and of the best available mitigation measures;
c. the remedial action taken, or proposed to be taken, by the offender to mitigate the harm;
d. whether the discharge or anticipated discharge was reported as required under the act;
e. any economic benefits accruing to the offender that, but for the offence, the offender would not have received; and
f. any evidence from which the court may reasonably conclude that the offender has a history of non-compliance with legislation designed to prevent or to

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[26] If a court is of the opinion that there is an equivalent provision in the *Canada Shipping Act* with a lesser penalty, the vessel or person found guilty of the contravention is liable to the lesser punishment (s. 38(2)).

minimize pollution (s. 191(4)).

Prosecution of offences under the *Shipping Act* must be commenced within 2 years after the Minister became aware of the subject-matter of the offence (s. 256(1)).

Mirroring the anti-pollution provisions of the *Fisheries Act*, Canadian courts have jurisdiction to enforce the anti-pollution provisions of the *Shipping Act* against foreign vessels, their owners and crew, even when lying off the coast of Canada (ss. 257-258).

Where the Minister of Transport believes on reasonable grounds that a vessel may discharge, or may have discharged, a prescribed pollutant, they may direct the vessel to proceed to designated location, by a route and in a manner specified by the Minister to (a) unload the pollutant, or (b) moor, anchor or remain there for any reasonable period that the Minister may specify (s. 189(d)).

The Minister of Transport also has the authority to direct a foreign vessel to leave Canadian waters (or not enter Canadian waters) if they have reasonable grounds to believe that the vessel has contravened an international convention, including MARPOL (s. 227(1)).

The *Shipping Act* also authorizes the Government of Canada (through the Governor in Council, on recommendation of the Minister of Transport) to make regulations respecting “the design, construction, manufacture and maintenance of vessels” (a), "inspections and testing of vessels” (g), and “the development, maintenance and implementation of a management system that sets out the manner in which marine environment protection measures are to be integrated into day-to-day navigation and shipping operation” (i), with a view toward “the protection of the marine environment from the impacts of navigation and shipping activities” (s. 35.1(1)).

Regulations have been enacted pursuant to the anti-pollution provisions of the *Shipping Act*, including the *Vessel Pollution and Dangerous Chemicals Regulations*, SOR/2012-69. Section 111(6) of this regulation governs the discharge of residues and washwater from exhaust gas cleaning systems, stating that:

> **Residues from exhaust gas cleaning systems**
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> (6) If a vessel operates an exhaust gas cleaning system that has been certified in accordance with Resolution MEPC.184(59), the vessel’s authorized representative must ensure that
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> (a) any exhaust gas cleaning system residues are delivered to an onshore reception facility; and
>
> (b) the washwater from the operation of the system, as well as the monitoring and recording of the washwater, meets the requirements of section 10 of the Resolution.

Section 10 of MARPOL Resolution MEPC.184(59) (“2009 Guidelines for Exhaust Gas Cleaning Systems”) establishes “Washwater discharge criteria”. These criteria impose limits on pH, oil content (as measured by Polycyclic Aromatic Hydrocarbons (“PAHs”)), turbidity, suspended solids, nitrates and additives in discharged washwater, and also impose the following monitoring and recording requirement:

> 10.1.1 When the EGC system is operated in ports, harbours, or estuaries, the washwater monitoring and recording should be continuous. The values monitored and recorded should include pH, PAH, turbidity and temperature. In other areas the continuous monitoring and recording equipment should also be in operation, whenever the EGC system is in operation, except for short periods of maintenance and cleaning of the equipment. The discharge water should comply with the following limits …”[27]

Resolution 184(59) also imposes requirements for the testing, monitoring and recording of EGC systems, including requirements that:

a. “The recording and processing device should be of robust, tamper-proof design with read-only capability” (s. 7.1);
b. Data should be recorded “against UTC and ships position by a Global Navigational Satellite System (GNSS)” (s. 7.2);
c. “Data should be retained for a period of not less than 18 months from the date of recording” and kept onboard (even if the unit is changed) (s. 7.4); and
d. “The device should be capable of downloading a copy of the recorded data and reports in a readily useable format. Such copy of the data and reports should be available to the Administration or port State authority as requested” (s. 7.5).

Returning to the *Vessel Pollution and Dangerous Chemicals Regulations* enacted pursuant to the *Shipping Act*, section 111.2 states that is a vessel operates an EGC system:

a. the vessel must hold and keep on board a certificate of type approval certifying that the system meets the applicable requirements referred to in Resolution MEPC.184(59);
b. the vessel must keep on board an EGC System Technical Manual “Scheme A” that meets the requirements of section 4.2.2 of Resolution MEPC.184(59) or an EGC System Technical Manual “Scheme B” that meets the requirements of section 5.6 of Resolution MEPC.184(59);
c. the vessel must keep on board a SOx Emissions Compliance Plan that meets the requirements of section 9.1.1 of Resolution MEPC.184(59);
d. the authorized representative must ensure that the information required by Resolution MEPC.184(59) respecting the operation, maintenance, servicing, adjustments and monitoring of the system is recorded as required by the Resolution; and
e. the vessel must keep on board the information referred to in paragraph (d) in the form and manner required by Resolution MEPC.184(59).

Other pertinent provisions in the *Vessel Pollution and Dangerous Chemicals Regulations* include Section 4, which defines “prescribed pollutants” as (a) oil and any

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[27] Resolution MEPC.184(59), *2009 Guidelines for Exhaust Gas Cleaning Systems*, adopted July 17, 2009 < https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/184(59).pdf >.

oily mixture; (b) garbage; and (c) organotin compounds that act as biocides. Sections 30 and 31 authorize the discharge of an oily mixture in certain circumstances. Section 96(1) authorizes the discharge of sewage in certain circumstances. Older vessels (defined as those with a keel laid before May 3, 2007 or delivered before May 3, 2010) are exempted from the sewage regulations, with the exception of vessels in the Great Lakes and St. Lawrence River above Montreal or vessels in a "designated sewage area" (generally pleasure craft mooring areas), which are all subject to the regulation (s. 84). Air pollution, including EGCSs as discussed above, is regulated at Division 6 (ss.108-125). The discharge of "pollutant substances" is prohibited at s. 126 except in certain circumstances, with substances enumerated in Schedule 1 of the regulation. Regulation of greywater discharge is provided for at s. 131.1. The obligation of a ship's master or operator of an oil-handling facility to report discharge of pollutants is provided for at ss. 132 to 133.

In 2022, Canada introduced "non-mandatory" environmental measures for cruise ships operating in waters under Canadian jurisdiction. The measures recommend that sewage and greywater not be discharged within 3 nautical miles of shore and that any sewage or greywater discharged between 3 and 12 nautical miles from shore should not leave a sheen or residue on the surface. The measures do not mention discharge of scrubber "washwater".[28]

D. Canada's Obligation to Enforce its Fisheries Act Under Article 24.4 of the USMCA

The *USMCA* imposes a prohibition on Canada (as well as on the United States and Mexico) against failing to enforce its own environmental laws.

Article 24.4 of Chapter 24 of the *USMCA* states that:

> 1. No Party shall fail to effectively enforce its environmental laws through a sustained or recurring course of action or inaction [3] in a manner affecting trade or investment between the Parties, [4, 5] after the date of entry into force of this Agreement.

The *USMCA* came into force on July 1, 2020.

Canada's *Fisheries Act*, RSC 1985, c F-14 is an environmental law pursuant to Article 24.1 of the *USMCA*, which is defined (for Canada) as "an Act of the Parliament of Canada or regulation made under an Act of the Parliament of Canada that is enforceable by action of the central level of government", "the primary purpose of which is the protection of the environment, or the prevention of a danger to human life or health, through:

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[28] Transport Canada, "New environmental measures for cruise ships in waters under Canadian jurisdiction – 2022 season," *Ship Safety Bulletin SSB No.:10/2022* (April 12, 2022; modified August 18, 2022) < https://tc.canada.ca/en/marine-transportation/marine-safety/ship-safety-bulletins/new-environmental-measures-cruise-ships-waters-under-canadian-jurisdiction-2022-season-ssb-no-10-2022-modified-august-18-2022 >.

(a) the prevention, abatement, or control of the release, discharge, or emission of pollutants or environmental contaminants;

(b) the control of environmentally hazardous or toxic chemicals, substances, materials, or wastes, and the dissemination of information related thereto; or

(c) the protection or conservation of wild flora or fauna,1 including endangered species, their habitat, and specially protected natural areas. …"[29]

The definition of environment laws in the *USMCA* expressly includes recognition that "'protection or conservation' may include the protection or conservation of biological diversity" and defines "Specially protected natural areas" as "those areas as defined by the Party in its law."[30] Exemptions in Art. 24.1 respecting worker safety and management of subsistence or aboriginal harvesting of natural resources are not applicable to Canada's *Fisheries Act*.

The prohibition at Article 24.4 is congruent with objectives articulated in Chapter 24 (at Art. 24.2), including to "promote high levels of environmental protection and effective enforcement of environmental laws." This article also states that: "The Parties recognize that the environment plays an important role in the economic, social, and cultural well-being of indigenous peoples and local communities, and acknowledge the importance of engaging with these groups in the long-term conservation of the environment."[31]

The Agreement recognizes "the sovereign right of each Party to establish its own levels of domestic environmental protection and its own environmental priorities, and to establish, adopt, or modify its environmental laws and policies accordingly," while stating that: "Each Party shall strive to ensure that its environmental laws and policies provide for, and encourage, high levels of environmental protection, and shall strive to continue to improve its respective levels of environmental protection" (Art. 24.3 – Levels of Protection).[32]

Determination of whether a particular course of action or inaction is "sustained" or "recurring", and therefore subject to the prohibition at Art. 24.4, is assisted with explanatory text in the footnotes:

> a "sustained or recurring course of action or inaction" is 'sustained" if the course of action or inaction is consistent or ongoing, and is "recurring" if the course of action or inaction occurs periodically or repeatedly and when the occurrences are related or the same in nature. A course of action or inaction does not include an isolated instance or case.[33]

A course of action or inaction "is deemed to be 'in a manner affecting trade or investment between the Parties' if the course involves: (i) a person or industry that

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[29] *USMCA*, ch. 24, art. 24.1.
[30] *USMCA*, ch. 24, art. 24.1, footnotes 1 and 2.
[31] *USMCA*, ch. 24, art. 24.2.
[32] *USMCA*, ch. 24, art. 24.3.
[33] *USMCA*, ch. 24, art. 24.4, footnote 3.

produces a good or supplies a service traded between the Parties or has an investment in the territory of the Party that has failed to comply with this obligation; or (ii) a person or industry that produces a good or supplies a service that competes in the territory of a Party with a good or a service of another Party."[34]

A Party accused of failing to enforce its environmental laws bears the burden of demonstrating that a purported failure is not in a manner affecting trade or investment between the Parties.[35]

Chapter 24 recognizes the right of Parties "to exercise discretion and to make decisions regarding: (a) investigatory, prosecutorial, regulatory, and compliance matters; and (b) the allocation of environmental enforcement resources with respect to other environmental laws determined to have higher priorities" (Art 24.4(2)). A Party is deemed to be in compliance with Art. 24.4(1) if "a course of action or inaction reflects a reasonable exercise of that discretion, or results from a *bona fide* decision regarding the allocation of those resources in accordance with priorities for enforcement of its environmental laws."[36]

However, the Agreement expressly recognizes that "it is inappropriate to encourage trade or investment by weakening or reducing the protection afforded in their respective environmental laws. Accordingly, a Party shall not waive or otherwise derogate from, or offer to waive or otherwise derogate from, its environmental laws in a manner that weakens or reduces the protection afforded in those laws in order to encourage trade or investment between the Parties" (Art. 24.4(3)).[37] As a result, economic motives behind non-enforcement of cruise-ship pollution are not a permissible basis for Canada's derogation of its environmental enforcement obligations under Chapter 24.

Chapter 24, Article 24.27(1) of the *USMCA* expressly provides for the right of any person of Canada, the United States or Mexico to "file a submission asserting that a Party is failing to effectively enforce its environmental laws."[38]

E. Evidence of Deposit of Deleterious Substances by Cruise Ships on Canada's Pacific Coast, including Scrubber Washwater, and Apparent Canadian Inaction

The harmful impact of cruise-ship effluent on fish, other marine species and human health is well documented.

More than 20 years ago, Linda Nowlan and Ines Kwan noted in their study *Cruise Control: Regulating Cruise Ship Pollution on the Pacific Coast of Canada* (2001) that:

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[34] *USMCA*, ch. 24, art. 24.4, footnote 4.
[35] *USMCA*, ch. 24, art. 24.4, footnote 5. This footnote states: "For purposes of dispute settlement, a panel shall presume that a failure is in a manner affecting trade or investment between the Parties, unless the responding Party demonstrates otherwise."
[36] *USMCA*, ch. 24, art. 24.4(2).
[37] *USMCA*, ch. 24, art. 24.4(3).
[38] *USMCA*, ch. 24, art. 24.27(1).

> "Sewage may have a deleterious effect on fish, by lowering the amount of oxygen in the water. The *Fisheries Act* has been used on numerous occasions to prosecute pollution offences in marine waters from a variety of sources. Yet no prosecutions have been brought against cruise ships to date for violations of the federal *Fisheries Act* in Canada."[39]

Proliferation of Exhaust Gas Cleaning Systems ("EGCSs")("scrubbers") on cruise ships in recent years — implemented by the shipping sector to comply with obligations under the *Montreal Protocol* to reduce emissions that deplete the ozone layer and to meet other domestic and international obligations — provide an "alternate" (or "equivalent") route to compliance. They allow vessel owners to continue burning cheaper, higher-sulphur-content fuel than would otherwise be permitted under MARPOL emission guidelines, particularly IMO 2020, a global regulation mandating the burning of cleaner fuels, and emissions regulations introduced in the North America Emissions Control Area ("ECA") in 2012.[40]

Scrubbers are installed to reduce costs and increase profits for vessel operators, by avoiding the increased costs of more expensive lower-sulphur fuel.

A consequence of this regulatory loophole is a heightened risk to marine species from cruise-ship operations. Scrubbers remove sulfur dioxides, heavy metals, polycyclic aromatic hydrocarbons ("PAHs"), and other toxins from ships' air-borne exhaust emissions and put these toxins into the ocean through "washwater" discharges.[41]

Scientists with the International Council for the Exploration of the SEA (ICES) have described the problem as follows:

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[39] Linda Nowlan and Ines Kwan, *Cruise Control: Regulating Cruise Ship Pollution on the Pacific Coast of Canada* (Vancouver: West Coast Environmental Law, 2021), p. 9. See also James P. Meador, Andrew Yeh, and Evan P. Gallagher, "Adverse Metabolic Effects in Fish Exposed to Contaminants of Emerging Concern in the Field and Laboratory," *Environmental Pollution*, 236 (May 2018): 850-861; James P. Meador, Andrew Yeh, Graham Young, and Evan P. Gallagher, "Contaminants of Emerging Concern in a Large Temperate Estuary," *Environmental Pollution*, 213 (June 2016): 254-267; James P. Meador, "Do Chemically Contaminated River Estuaries in Puget Sound (Washington, USA) Affect the Survival Rate of Hatchery-reared Chinook Salmon?," *Canadian Journal of Fisheries and Aquatic Sciences*, 71, no. 1 (January 2014).

[40] Montreal Protocol on Substances that Deplete the Ozone Layer, done at Montreal, September 16, 1987 (the "*Montreal Protocol*"). See also *USMCA*, ch. 24, art. 24.9. For a discussion of emissions from maritime transport in North America, see CEC, *Reducing Emissions from Goods Movement via Maritime Transportation in North America* (Montreal, QC: Commission for Environmental Cooperation, 2018).

[41] Bryan Comer, Elise Georgeoff and Liudmila Osipova, *Air Emissions and Water Pollution Discharges from Ships with Scrubbers* (Washington, DC: International Council on Clean Transportation, November 2020); Elise Georgeoff, Xiaoli Mao, and Bryan Comer, *A Whale of a Problem: Heavy Fuel Oil, Exhaust Gas Cleaning Systems, and British Columbia's Resident Killer Whales*" (Washington, DC: International Council on Clean Transportation, 2019); STAND.earth, *Covid Pandemic Results in a Cleaner Coast: An Investigation into Unregulated Cruise Ship Pollution in Canada's West Coast Waters* (2020), p. 12; Erik Stokstad, "Shipping rule cleans the air but dirties the water," *Science* (May 13, 2021); Richa Syal, "Shipping's dirty secret: how 'scrubbers' clean the air – while contaminating the sea," *Guardian* (July 12, 2022).

> "Transferring contaminants from air emissions to the ocean does not mitigate their impact and instead, the use of scrubber systems is creating an emerging global problem. The growing use of scrubbers by ships to meet the reduced sulphur emission limits will yield significant amounts of acidic and contaminated scrubber discharge water. Scrubber discharge water is documented to comprise a cocktail of heavy metals, PAHs and other organic compounds which have not yet been identified. This mixture has demonstrated the potential for substantial toxic effects in laboratory studies, causing immediate mortality in plankton and exhibiting negative synergistic effects. The substances found in scrubber discharge water are likely to have further impacts through bioaccumulation, acidification and eutrophication in the marine environment. While a single ship with an installed scrubber may pose limited, local risk to marine ecosystem health, a global shipping community employing scrubbers to meet air emission limits is of serious concern. The impacts of scrubber discharge water can be completely avoided through the use of alternative fuels, such as distilled low sulphur fuels. Distilled fuels have the added benefit that they remove the threat of heavy fuel oil spills from shipping activities. If the use of distilled fuels is not adopted, then there is urgent need for:
>
> (1) significant investment in technological advances and port reception facilities to allow zero discharge closed loop scrubber systems;
> (2) improved protocols and standards for measuring, monitoring and reporting on scrubber discharge water acidity and pollutants;
> (3) evidence-based regulations on scrubber water discharge limits that consider the full suite of contaminants."[42]

The World Wildlife Fund has further noted that: "Washwater is acidic and contains large amounts of heavy metals and polycyclic aromatic hydrocarbons, which can be toxic and have carcinogenic properties. It also reduces the ocean's ability to buffer climate change—for every tonne of sulfur dioxide discharged by scrubbers, the ocean will be unable to absorb about half a tonne of carbon dioxide from the atmosphere."[43]

This warning of the global effects of scrubber washwater discharge was echoed by the International Maritime Organization's Task Team on Exhaust Gas Cleaning Systems (convened by GESAMP, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), which stated in 2019 that: "it was clear that an approach taking into account potential global effects with respect to acidification and eutrophication would put the risk assessment of exhaust gas effluent contaminants into the correct context."[44] The task team "identified data gaps in the (eco-)toxicological effects area of the relevant exhaust gas effluents contaminants" and noted substantial uncertainties regarding harms arising from discharge of scrubber washwater:

> "In the area of EGCS there exist still many uncertainties: the amount of substances in the exhaust gas was rather small but the number of substances huge, their toxicological (human health) and

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[42] I.M. Hassellöv et al, "ICES Viewpoint Background Document: Impact from Exhaust Gas Cleaning Systems (scrubbers) on the Marine Environment (Ad Hoc)," *ICES Scientific Reports*, vol. 2, no. 86 (2020), p. 32. See also Erik Ytreberg et al, "Effects of scrubber washwater discharge on microplankton in the Baltic Sea," *Marine Pollution Bulletin*, 145 (August 2019): 316-324.
[43] S. Davin et al. *National Vessel Dumping Assessment: Quantifying the Threat of Ship Waste to Canada's Marine Protected Areas* (Toronto: World Wildlife Fund, 2022), p. 6.
[44] GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), *Exhaust Gas Cleaning Systems: A Roadmap to Risk Assessment* (International Maritime Organization, Sub-Committee on Pollution Prevention and Response, December 2019), p. 14.

> ecotoxicological (aquatic organisms) effects are in many cases insufficiently known and the behavior in the environment ((bio-)degradation and sorption) was unknown for many substances, etc."[45]

The task team stated that it was "not able to conclude on the risks of EGCS discharges to the marine environment as it identified several uncertainties and data gaps."[46] The GESAMP task group did, however, state that: "In terms of total amounts of contaminant discharges through EGCS, it appeared that large scale uses of these systems may lead to deterioration of environmental status, especially in the ecologically vulnerable and sensitive areas such as coastal waters, semi-enclosed seas and also in ports and harbours."[47]

STAND Environmental Society ("STAND") and West Coast Environmental Law ("WCEL") have also identified the problem of scrubber pollution. Our 2022 report *Regulating the West Coast Cruise Industry* describes how: "Vast quantities of washwater are deposited in ocean waters in an attempt to remove sulfur dioxides from the heavy fuel oil combustion exhaust pouring from cruise ship smokestacks. Washwater may sound benign, but it is full of heavy metals and organic compounds that threaten human health and aquatic ecosystems."[48]

We discussed the scale of the problem on Canada's Pacific Coast, applying data and analysis from researchers with the International Council for Clean Transportation ("ICCT"):

> "[M]ore than a million passengers will arrive on dozens of voyages through the waters off BC on their way to and from Alaska, leaving in their wake more than 31 billion litres of inadequately treated cruise ship pollution laden with fecal coliform, ammonia, heavy metals and polycyclic aromatic hydrocarbons—pollutants that are harmful to human health, aquatic organisms and coastal ecosystems."[49]

We quantified the volume of sewage, greywater and washwater discharged from a single cruise ship on the Pacific Coast in 2020 (relying on data compiled by Vard Marine Inc. for the World Wildlife Fund):

> "A cruise ship the size of the Royal Princess, for instance, owned by Carnival Corporation and one of 30 cruise ships that routinely sail Canadian waters between Vancouver and Alaska, on a one-week voyage dumps more than one million litres of human sewage and 8.7 million litres of highly polluting greywater (from sinks, baths, showers, laundry, galleys, spas, salons, workshops,

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[45] GESAMP, *Exhaust Gas Cleaning Systems: A Roadmap to Risk Assessment*, pp. 14 and 91.
[46] GESAMP, *Exhaust Gas Cleaning Systems: A Roadmap to Risk Assessment*, p. 94.
[47] GESAMP, *Exhaust Gas Cleaning Systems: A Roadmap to Risk Assessment*, p. 96.
[48] STAND and WCEL, *Regulating the West Coast Cruise Industry: Canada at the Low Water Mark: An Investigation into the Regulations for Cruise Ship Pollution along the West Coast from California to Alaska* (Vancouver: STAND AND WCEL, 2022), p. 1; Kevin Jiang, "'They treat us like a toilet bowl': Cruise ships dump billions of litres of toxic waste in Canada, report finds," *Toronto Star*, July 19, 2022. See also STAND, *Covid Pandemic Results in a Cleaner Coast* (2020).
[49] STAND and WCEL, *Regulating the West Coast Cruise Industry*, p. 1; Comer, Georgeoff and Osipova, *Air Emissions and Water Pollution Discharges from Ships with Scrubbers* (2020), p. 4; Georgeoff, Mao, and Comer, *A Whale of a Problem* (2019).

> print and photo shops, dry cleaners and medical facilities) into BC's coastal waters, enough wastewater to fill four Olympic swimming pools. Add to this a potential estimated 200 million litres or so (80 more Olympic swimming pools) of chemical-laden washwater that could be discharged from its fuel system, and they've dumped pollution from one weeklong cruise equivalent to 11 times the volume of all the tanks in the Vancouver Aquarium.[50]

International Council for Clean Transportation research scientists have examined and described the water pollutants emitted from scrubber discharge water on the BC coast:

> Regarding water pollutants, we found that all scrubbers—open loop, closed loop, and hybrid—discharge water that is more acidic and turbid than the surrounding water. Additionally, all scrubbers emit nitrates, PAHs, and heavy metals. The acids that scrubbers emit contribute to ocean acidification. Discharge from open-loop scrubbers was typically more acidic than bleed-off water discharges from closed-loop systems. Turbid water degrades water quality and the suspended PM in turbid water can contain PAHs and heavy metals. We found that closed-loop bleed-off water was more turbid than open-loop discharges. We did not have enough information to determine which system—open or closed—emits more nitrates. Discharging nitrates contributes to acidification and can lead to eutrophication.[51]

Applying this research to marine species on the Pacific coast, we described the impacts of sewage, greywater and washwater discharges as follows:

> "Untreated and poorly treated sewage contains large amounts of fecal coliform, nitrogen and phosphorus, and can also contain heavy metals, pharmaceuticals and plastic. Sewage can contribute to eutrophication and algal blooms and pollute filter-feeding shellfish. Sewage solids can cause increased turbidity that can alter the marine habitat on the bottom of the ocean. Sewage is also visually repulsive and can pose health-related hazards for water sports like swimming, scuba diving, and surfing.
>
> Greywater may pose greater threats than sewage discharges due to the greater volumes being dumped into coastal waters. Like sewage, it can contain a variety of toxic chemicals, nutrients, heavy metals, oils, and fecal coliforms and other pathogens. When released into the marine environment, greywater can create harmful algal blooms and dead zones, as well as suffocate fish, crabs, lobsters and sponges. These impacts can have wide-ranging effects, decreasing biodiversity and disrupting food webs.
>
> The largest source by far of marine pollution comes from 31 billion litres of scrubber-created washwater, which contains carcinogenic and other toxic substances, such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals. Like sewage and greywater, exposure to washwater can harm aquatic organisms and food webs. Heavy metals and PAHs are persistent in the marine environment and can accumulate in sediment, which negatively affects bottom-feeders. Even low PAH concentrations can cause liver damage and reduce fertility in fish. Nitrates can increase risk of eutrophication in the summer months when algal bloom and cruise ships schedules overlap.
>
> When released into the ocean, the wide array of toxic substances in these multiple cruise ship water pollution waste streams pose a significant, compounding threat to aquatic wildlife and the habitat and food webs on which they depend, including the recovering but threatened sea otter

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[50] STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 7; Vard Marine Inc., *Greywater Generation Estimates for the BC Coast, Report #381-000* (17 June 2019).

[51] Comer, Georgeoff and Osipova, *Air Emissions and Water Pollution Discharges from Ships with Scrubbers* (2020), p. 29; Georgeoff, Mao, and Comer, *A Whale of a Problem* (2019); Erik Stokstad, "Shipping rule cleans the air but dirties the water," *Science* (May 13, 2021).

> populations and threatened and critically endangered populations of resident killer whales that live off the coast of British Columbia."[52]

The ICCT researchers provide a further detailed analysis of toxin-laden scrubber washwater discharged from cruise ships in the critical habitat of the endangered Resident Killer Whale population in the Great Bear Sea and Salish Sea between the Ports of Prince Rupert, Vancouver, Victoria, and Seattle:

> In 2017, washwater discharges totaled 35 million tonnes. About 10% of discharges occurred within RKW critical habitat, even though, geographically, these habitats represent only 0.6% of the study area. In 2017, HFO use and washwater discharges were mainly from cruise ships, with container ships a distant second (Figure 8). Cruise ships accounted for 23, or 77%, of the 30 ships with scrubbers in 2017. They emitted 31 million, or nearly 90%, of the 35 million tonnes of washwater discharged in the region (Figure 9). Cruise ships often sail through the Johnstone Strait, leading to high washwater discharges inside the northern RKW critical habitat. When cruises leave Victoria, washwater discharges occur within the southern RKW critical habitat.
>
> By 2020, we predict a 35% increase in total scrubber washwater discharges to about 47 million tonnes. Washwater discharges within RKW critical habitat is expected to grow by 45% to nearly 5 million tonnes by 2020. We predict HFO use and washwater discharges to increase from 2017 to 2020 for container ships and bulk carriers (Figure 9). Additionally, we expect some ship types that were not outfitted with scrubbers in 2017 to start using them, including roll-on/roll-offs, oil and chemical tankers, general cargo ships, and others.
>
> Under an extreme scenario, washwater discharges nearly quadruple from 2017, reaching more than 130 million tonnes in total, with 18 million tonnes in RKW critical habitat. Container ships, cruise ships, and bulk carriers discharge the greatest quantities of washwater in the extreme case.[53]

The ICCT researchers described the impacts of the washwater on the endangered Resident Killer Whales as follows:

> "[E]ven with scrubbers, ships will continue to emit air and climate pollution emissions such as particulate matter, sulfur oxides, nitrogen oxides, black carbon, and carbon dioxide. As a consequence, ships with scrubbers will continue to pose both direct and indirect risks to aquatic wildlife, including threatened and endangered species such as RKWs. Unfortunately, British Columbian killer whales are already considered the most contaminated marine mammal species in the world, as measured by polychlorinated biphenyl (PCB) concentrations, which increases their risk for toxic effects (Ross, Ellis, Ikonomou, Barrett-Lennard, & Addison, 2000). …
>
> Polycyclic aromatic hydrocarbons and heavy metals are of particular concern for marine mammals. Even if ships discharge low concentrations of these contaminants, they accumulate in the environment and bioaccumulate in the food web. Over time, pollutant concentrations will increase, especially in shallow, coastal areas where dilution is limited and vessel traffic is high (Endres et al., 2018). Exposure to PAHs and heavy metals has been linked to negative health outcomes for other marine mammal species, such as beluga whales and pinnipeds. These effects are generalized to killer whales due to the similar physiological processes of marine mammals (Ross, 2000). Additionally, synergistic effects of exposure to scrubber washwater could be important. Researchers at IVL Swedish Environmental Research Institute suggested the

[52] Comer, Georgeoff and Osipova, *Air Emissions and Water Pollution Discharges from Ships with Scrubbers* (2020); Georgeoff, Mao, and Comer, *A Whale of a Problem* (2019); STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 13.
[53] Georgeoff, Mao, and Comer, *A Whale of a Problem* (2019), p. 18.

> combined effects of exposure to washwater contaminants on zooplankton, which form the basis of the food web for many species, may be dramatically different than the effect of exposure to only one pollutant (Magnusson et al., 2018). …
>
> PAHs are persistent organic pollutants, which means they resist biodegradation. When RKWs eat contaminated fish, PAHs are stored in the RKWs' fat reserves, including their protective blubber layer (Formigaro et al., 2014). When RKWs draw upon their fat reserves for energy, problems can occur. PAHs damage DNA, which can cause cancer (Munoz & Albores, 2011). On the east coast of North America in the St. Lawrence estuary, high PAH concentrations in Beluga whales corresponded to higher rates of digestive tract cancers (Martineau et al., 2002).
>
> Heavy metals are naturally occurring elements found in the earth's crust. Some heavy metals are essential nutrients at lower concentrations, such as copper, zinc, and iron, while others, such as lead, mercury, and cadmium, are toxic in any amount. Heavy metals are neither biodegradable nor water soluble. They can bioaccumulate in tissues of animals, including the fish that RKWs eat. While Orcas, including RKWs, have proteins that bind and detoxify mercury, these capabilities are limited, and when mercury levels are high, they can bypass the proteins and cause toxicity (Buckman et al., 2011).
>
> Heavy metals accumulate in the liver, bone marrow, and kidneys (Dosi, 2000). Stored heavy metals are released during pregnancy, lactation, migration, and when food is scarce (Marsili et al., 2001). With Chinook salmon fisheries declining, especially in southern British Columbia waters, nutritional stress is causing RKWs to tap into their blubber resources, releasing these stored pollutants (Fisheries and Oceans Canada, 2018b). Exposure to toxic compounds including PAHs and heavy metals were coincident with cancers in populations of beluga whales in the St. Lawrence River (Guise, Lagacé, & Béland, 1994). Besides carcinogenic effects, chronic intake of heavy metals suppresses the immune system (Kakuschke & Prange, 2007.). Exposure to copper, mercury, and lead has been associated with reproductive dysfunction, difficulty locating prey, and poor metabolism in marine mammals (Jakimska, Konieczka, Skóra, & Namiesnik, 2011).[54]

While the United States has taken action to curb marine pollution from cruise ships along the Pacific Coast — at both the federal level through prosecutions initiated by the US Environmental Protection Agency ("EPA") as well as through state regulations and enforcement in Alaska, Washington State and California — Canada lags far behind, largely vacating the field to "voluntary compliance."[55]

STAND and WCEL discussed this problem in their 2021 report, noting that "Canada's cruise ship pollution regulations have lagged behind the regulations in other places":

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> "When the federal government adopted the Vessel Pollution and Dangerous Chemicals (VPDC) Regulations in 2012, they were already the weakest protections against cruise ship pollution on the West Coast of North America from California to Alaska. Neighboring jurisdictions in Washington State and Alaska had recognized the threat of a rapidly expanding cruise ship industry more than a decade earlier, and passed a suite of laws and regulations that held cruise

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[54] Georgeoff, Mao, and Comer, *A Whale of a Problem* (2019), pp. 19–20.

[55] See US EPA, *Cruise Ship Discharge Assessment Report*, *EPA842-R-07-005* (Washington, DC: US EPA, December 29, 2008); Claudia Copeland, *Cruise Ship Pollution: Background, Laws and Regulations, and Key Issues* (Washington, DC: Congressional Research Service, November 2008); US EPA, *Graywater Discharges from Vessels, EPA-800-R-11-001* (Washington, DC: US EPA, November 2011). For examples of Alaska's regulatory approach, see Alaska Department of Environmental Conservation, *2019 Annual Compliance Report Cruise Ship Wastewater* (February 2020); Alaska Department of Environmental Conservation, *2019 Ocean Ranger Annual Report* (December 2019).

> ship operators accountable for the vast amounts of water pollution these floating cities create on their voyages up and down the West Coast."[56]

Even in the United States where environmental regulation and enforcement is stronger, research has shown that cruise-ship operators consistently perform below the required minimum standards for sewage and waste-water treatment:

> "[T]he use of outdated or poorly maintained marine sanitation devices on ships does not mean adequate sewage treatment. The U.S. EPA found that sewage treated with this antiquated technology often contains significant amounts of fecal bacteria, heavy metals, and nutrients in excess of federal water quality standards. A study conducted by the State of Alaska found treated blackwater (sewage) and greywater samples to have registered fecal coliform levels as high as 9 to 24 million colonies per 100 millilitre sample, which exceeds the United States limit by 10,000 to 100,000 times. Of the 22 ships involved in the study, none were in full compliance with blackwater standards and 75% exceeded the American coliform standard."[57]

In comparison with other jurisdictions, including jurisdictions in the United States, Canadian law does little to prevent pollution of the marine environment by cruise ships operating along the Pacific Coast. This legislative gap was explained more than two decades ago in the study *Cruise Control: Cruise Control: Regulating Cruise Ship Pollution on the Pacific Coast of Canada* (2001):

> "The US and Alaskan governments have recognized the importance of environmental protection to the continued development of the cruise ship market and have developed an extensive set of regulatory requirements to effectively monitor and restrict cruise ship pollution.
>
> These regulations include the newly passed Alaskan Commercial Passenger Vessel Regulation and Fees law developed after a voluntary pollution control program was shown to be ineffective in the face of growth in the cruise industry.
>
> Tighter restrictions were also imposed in the US after evidence of the industry's poor environmental record were made public. Between 1993 and 1998, there were 104 American prosecutions against cruise ships for pollution offences. Prosecutions resulted in over $30 million (US) dollars in corporate fines.
>
> … Where controls and regulations exist in the United States none exist in Canada: there are no standards for grey water discharge and no general prohibitions on untreated sewage discharge. American standards for hazardous and solid wastes are considerably stronger than Canadian standards."[58]

In 2017, the U.S. Department of Justice ordered Carnival's Princess Cruise Lines to pay a $40 million fine—the largest ever—when five Princess Cruise Line vessels were

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[56] STAND and West Coast Environmental Law, *Regulating the West Coast Cruise Industry*, p. 1.
[57] STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 10; Karen Gorecki and Bruce Wallace, *Ripple Effects: The Need to Assess the Impacts of Cruise Ships in Victoria, B.C*. (Victoria: Vancouver Island Public Interest Research Group, 2003) < https://creansociety.ca/publications/2017/3/16/ripple-effects-the-need-to-assess-the-impacts-of-cruise-ships-in-victoria-bc >.
[58] Linda Nowlan and Ines Kwan, *Cruise Control: Regulating Cruise Ship Pollution on the Pacific Coast of Canada* (Vancouver: West Coast Environmental Law, 2021), pp. 3-4.

caught illegally dumping oil-contaminated waste for nearly a decade, tampering with pollution monitoring equipment, and falsifying logs to hide its actions.[59]

STAND has noted that: “Dozens of Carnival’s pollution-generating cruise ships, including the *Westerdam*, use Victoria’s cruise terminal as a stopover on their journeys between Seattle, Washington, and Ketchikan, Alaska.”[60] Records maintained as part of litigation between the US Environmental Protection Agency and Princess Cruise Lines show problems with EGC systems aboard at ships that call at the Port of Victoria, such the *Ruby Princess* (which called at Victoria 17 times in 2022) and the *Noordam*.[61]

In contrast to enforcement action in the United States, the Government of Canada appears to relegate protection of the marine environment to “voluntary compliance” by industry — an approach that has been shown to produce unsatisfactory results and which fails to uphold the public interest in protecting marine ecosystems.

As noted above, Transport Canada introduced voluntary measures for cruise ship discharges in 2022, while postponing mandatory regulations to future years.[62] STAND has previously noted that Transport Canada’s *Pollution Prevention Guidelines for the Operation of Cruise Ships Under Canadian Jurisdiction* (2013) are entirely voluntary, permitting Carnival and other cruise-ship operators “to treat B.C.’s beautiful and sensitive marine ecosystems as the world’s largest tourist toilet bowl.”[63]

In 2022, approximately 370 ships arrived at Ogden Point at the Port of Victoria, BC — as the total number of ships calling at Victoria each year nearly doubled over the proceeding decade.[64]

The weak statutory and regulatory regime in Canada is particularly troubling in light of its international obligations to protect the marine environment as outlined above.

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[59] United States Department of Justice, “Cruise Line Ordered to Pay $40 Million for Illegal Dumping of Oil Contaminated Waste and Falsifying Records,” April 19, 2017 < https://www.justice.gov/opa/pr/cruise-line-ordered-pay-40-million-illegal-dumping-oil-contaminated-waste-andfalsifying >; STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 8. See also Nowlan and Kwan, *Cruise Control*, p. 7.
[60] STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 8.
[61] Exhibit A, “January 6, 2021 Quarterly Issue Tracker,” pp. 38, 40, in *United States v. Princess Cruise Lines, Ltd.*, 1:16-cr-20897 (S.D. Fla.); Greater Victoria Harbour Authority, “2022 Cruise Ship Schedule – Ogden Point, Victoria, BC” < http://www.victoriacruise.ca/page/cruise-schedule > accessed October 4, 2022).
[62] Transport Canada, “New environmental measures for cruise ships in waters under Canadian jurisdiction – 2022 season,” *Ship Safety Bulletin SSB No.:10/2022* (April 12, 2022; modified August 18, 2022) < https://tc.canada.ca/en/marine-transportation/marine-safety/ship-safety-bulletins/new-environmental-measures-cruise-ships-waters-under-canadian-jurisdiction-2022-season-ssb-no-10-2022-modified-august-18-2022 >.
[63] STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 9.
[64] STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 9; “Victoria’s Cruise Ship Conundrum,” *Capital Daily*, December 2, 2019 < https://www.capnews.ca/news/cruise-ship-victoria-ogdenpoint-carbon-climate > (accessed February 3, 2023); Greater Victoria Harbour Authority, “2022 Cruise Ship Schedule – Ogden Point, Victoria, BC” < http://www.victoriacruise.ca/page/cruise-schedule > accessed October 4, 2022).

Returning to Canada's obligations under the *US-Mexico-Canada Agreement* (2020) and the problem of scrubber pollution, we note the obligation of parties (including Canada) to ensure that truthful information is available regarding products that purport to improve environmental performance. Pursuant to Article 24.14(3), Canada should ensure that any voluntary mechanisms for the promotion of products to improve environmental performance are "are truthful, are not misleading, and take into account relevant scientific and technical information" and "are based on relevant international standards, recommendations, guidelines, or best practices, as appropriate."[65]

F. Ecological Values of the Marine Environment of the Pacific Coast and the Need for Transnational Action and Cooperation, including Action by Canada

The Commission for Environmental Cooperation (the "CEC") (created through *NAFTA* and continued under the *USMCA*), has authored or commissioned a number of studies highlighting the ecological values of the marine environment and the need for transnational state action to protect these values from multiple risks.

In its study on *Ecological Regions of North America: Toward A Common Perspective* (1997), the CEC noted that the Marine West Coast Forest ecological region "has some of the most productive rivers for salmon production and there are many important estuaries." The study noted that the region's "marine environments are typified by large numbers of whales (including the killer whale), sea lions, seals and dolphins. Salmon, steelhead and associated spawning streams are located throughout this area. Coastal up-welling and freshwater discharge from coastal rivers into ocean waters stimulate the occurrence of abundant marine life."[66]

The CEC further noted that:

> "Issues regarding water quality standards, biological criteria, and non-point source pollution control have become major concerns in recent years. Like other aspects of ecosystem quality, problems involving aquatic ecosystems do not recognize political boundaries. Typically, water quality-related problems are dealt with on a watershed or river basin level. Although basin boundaries are important to identify as areas that influence the quality and quantity of water at a point on a river, many resource management agencies, at both the national and regional levels, recognize that the areas having the most effect on the quality and quantity of water do not correspond to basin boundaries.
>
> Whereas watersheds and basins merely define topographic drainage areas (where that is possible), ecological regions encompass the spatial similarities of combinations of characteristics that cause or reflect differences in the quality, health and integrity of ecosystems. As such, ecological regions have been shown to be effective for structuring water resource regulatory programs and for biological monitoring. … Ecological regions also provide a critical mechanism for

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[65] *USMCA*, ch. 24, art. 24.14(3).

[66] Commission for Environmental Cooperation, *Ecological Regions of North America: Toward A Common Perspective* (Montreal: Commission for Environmental Cooperation, 1997), p. 23.

> dealing with water quality problems and the assessment and management of aquatic ecosystems on an international scale.[67]

With respect to human impacts on ecosystems, the CEC stated that: "Anthropogenic inputs to the ecosystems, such as fertilizer or pesticides, often vary from one political unit (county, state, province or country) to another and may lead to degradation of water quality."[68]

STAND has described the biological diversity of the Salish Sea and Great Bear Sea ecoregions as follows:

> "This includes Puget Sound, the Strait of Juan De Fuca, and the Strait of Georgia, a unique transboundary marine ecosystem known by Indigenous Peoples and the geographic boards of both Canada and the U.S. as the Salish Sea. It is home to the endangered southern resident killer whale population and the declining chinook salmon population on which they depend. Cruise ships also sail through the Johnstone Strait into the Great Bear Sea, another of B.C.'s unique marine ecosystems, where a threatened population of sea otters and the threatened northern resident killer whale population eke out an existence alongside dwindling salmon populations."[69]

To safeguard the vital marine resources and values of the Salish Sea and Great Bear Sea ecoregions, transnational efforts concerning pollution from cruise ships and other vessels are required.[70] The CEC has noted that transnational, ecosystem-based approaches "are essential in evaluating environmental-economic conflicts arising from the demands of society over time."[71] Transnational ecosystem-based action is particularly important in the context of climate change, which as the Government of Canada has noted is impacting natural and human systems in profound ways: "Changing climate is increasingly affecting the rate and nature of change along Canada's highly dynamic coasts, with widespread impacts on natural and human systems."[72]

Approaching the problem of cruise-ship pollution through a transnational ecosystem and water-management lens is necessary and overdue. Cooperation between Canada and the United States on water and watershed management planning, environmental degradation detection, monitoring, regulation and enforcement — with encouragement from the CEC — can mitigate further damage and risks to ecological values and human

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[67] Commission for Environmental Cooperation, *Ecological Regions of North America: Toward A Common Perspective* (1997), p. 42.
[68] Commission for Environmental Cooperation, *Ecological Regions of North America: Toward A Common Perspective* (1997), p. 42.
[69] STAND, *Covid Pandemic Results in a Cleaner Coast* (2020), p. 8.
[70] For a discussion of this kind of a binational planning and management approach, see Commission for Environmental Cooperation, *Ecological Regions of North America: Toward A Common Perspective* (1997), p. 46.
[71] For a discussion of this kind of a binational planning and management approach, see Commission for Environmental Cooperation, *Ecological Regions of North America: Toward A Common Perspective* (1997), p. 46.
[72] D.S. Lemmen et al, eds., *Canada's Marine Coasts in a Changing Climate* (Ottawa: Government of Canada, 2016), p. 3.

health, including supporting survival and recovery of the Southern Resident Killer Whale ("SRKW") population and other species at risk.[73]

Joint action by the United States and Mexico on water and marine pollution in the Tijuana-San Diego metropolis since the 1990s is instructive in identifying an effective strategy for risks facing the marine environment within the Salish Sea and Great Bear Sea ecoregions, including risks posed by cruise-ship pollution.[74]

The CEC has identified "Reducing Pollution from Maritime Transport" as a cooperative project and strategic priority, stating that: "The marine transport of trade between Canada, Mexico, and the United States, and with global trading partners, supports our economies and well-being. It also produces high levels of pollution that impact our air and water quality and the health of our communities."[75]

Canada has taken preliminary steps toward transnational action to support survival and recovery of the SRKW population, including establishing the Contaminants Technical Working Group (TWG) in 2018, led by Environment and Climate Change Canada and consisting of officials from several federal government departments as well as agencies in British Columbia and Washington State. In 2020, the TWG identified "gaps for SRKW recovery, with respect to the threat of contaminants" and recommended implementation of "further controls to reduce the threat of contaminants." The TWG also recommended that partner agencies: "Make informed decisions that take into account available scientific data."[76] To our knowledge, further regulatory controls to reduce the threat of contaminants to SRKWs have not been developed or implemented by Canada.[77]

We strongly endorse effective joint action by Canada and the United States to reduce marine pollution from cruise ships on the Pacific Coast and to protect vital ecosystems and endangered species in the Salish Sea and Great Bear Sea ecoregions.

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[73] The Southern Resident Killer Whale (Whale, Killer [Orcinus orca] Northeast Pacific southern resident population) is listed as an Endangered Species under Schedule 1, Part 2 of the *Species at Risk Act*, SC 2002, c 29

[74] Richard Wright, Kathryn Ries, and Alain Winckell. Eds, *Identifying priorities for a Geographic Information System (GIS) for the Tijuana River Watershed:* (San Diego: Institute for Regional Studies of the Californias, San Diego State University, 1995); Commission for Environmental Cooperation, *Ecological Regions of North America: Toward A Common Perspective* (1997), pp. 45-46.

[75] CEC, *Operational Plan of the Commission for Environmental Cooperation 2017-2018* (Montreal, QC: CEC, 2017), p. 3.

[76] Government of Canada, *2020 Southern Resident Killer Whale Contaminants Technical Working Group Accomplishment Highlights and Recommendations* (Updated June 23, 2021).

[77] Government of Canada, *Southern Resident Killer Whales Contaminants Technical Working Group – 2022 Recommended Actions on Contaminants* (updated December 13, 2022).

Conclusion

In conclusion, we are concerned that Canada may be in breach of its obligations under the *US-Mexico-Canada Agreement* (2020), *MARPOL* and other international instruments to prevent pollution of the marine environment by the shipping sector, including cruise ships operating along the Pacific coast, particularly in respect of Canada's obligation to enforce s. 36(3) of the *Fisheries Act*.

Specifically, we request the following information:

1. The number of investigations initiated against cruise ship operators between January 1, 2018 and December 31, 2022 in respect of compliance with s. 36(3);

2. The number of prosecutions initiated against cruise ship operators between January 1, 2018 and December 31, 2022 in respect of breaches of s. 36(3);

3. Particulars of any penalties imposed against cruise ship operators between January 1, 2018 and December 31, 2022 for contraventions of s. 36(3);

4. The number of applications the Department of Environment and Climate Change received between January 1, 2018 and December 31, 2022 to authorize cruise ship operators to discharge deleterious substances, pursuant to s. 36(4) and the *Wastewater Systems Effluent Regulations*, SOR/2012-139, and the particulars of these applications;

5. The number of applications the Department of Environment and Climate Change approved between January 1, 2018 and December 31, 2022 authorizing cruise ship operators to discharge deleterious substances, pursuant to s. 36(4) and the *Wastewater Systems Effluent Regulations*, SOR/2012-139, and the particulars of these applications;

6. Particulars of any investigations, contraventions or penalties regarding the performance, monitoring or reporting of Exhaust Gas Cleaning Systems ("EGCSs") in cruise ships operating along the Pacific coast of Canada between January 1, 2018 and December 31, 2022; and

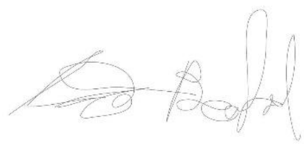
7. Any rationale for non-enforcement of subsection 36(3) of the *Fisheries Act* against cruise ship operators.

As stated above, we seek this information to determine whether Canada is fulfilling its international and domestic obligations to enforce its environmental laws and prevent pollution of the marine environment from the shipping sector, particularly pollution caused by Exhaust Gas Cleaning Systems on cruise ships on the Pacific Coast.

We request a timely response to this letter, to allow us to properly evaluate our options, including a possible remedy under Article 24.4 of Chapter 24 of the *USMCA* in respect of s. 36(3) of the *Fisheries Act*.[78]

Thank you for your assistance in obtaining this information.

Sincerely,



Anna Barford,
Canada Shipping Campaigner
STAND.Earth

cc. Hon. Joyce Murray, Minister of Fisheries and Oceans
Hon. Omar Alghabra, Minister of Transport

Attachments:

1. Elise Georgeoff, Xiaoli Mao, and Bryan Comer, *A Whale of a Problem: Heavy Fuel Oil, Exhaust Gas Cleaning Systems, and British Columbia's Resident Killer Whales*" (Washington, DC: International Council on Clean Transportation, 2019)

2. Bryan Comer, Elise Georgeoff and Liudmila Osipova, *Air Emissions and Water Pollution Discharges from Ships with Scrubbers* (Washington, DC: International Council on Clean Transportation, November 2020)

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[78] *USMCA*, ch. 24, art. 24.4.

A whale of a problem?

Heavy fuel oil, exhaust gas cleaning systems, and British Columbia's resident killer whales

Elise Georgeff, Xiaoli Mao, Bryan Comer, PhD

ICCT CONSULTING REPORT

ACKNOWLEDGEMENTS

Thank you to the World Wildlife Fund for funding this analysis. Thank you, as well, to our colleague Amy Smorodin for reviewing an earlier version of this report.

International Council on Clean Transportation
1500 K Street NW Suite 650
Washington DC 20005 USA

communications@theicct.org | www.theicct.org | @TheICCT

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In 2020, the International Maritime Organization (IMO) will begin to enforce a fuel sulfur limit of 0.5% by mass (5,000 ppm), down from a maximum limit of 3.5%. Some shipowners have invested in exhaust gas cleaning systems, known as "scrubbers," in order to comply with the regulations without having to switch to cleaner and more expensive fuels. Scrubbers, especially open-loop systems, have harmful unintended consequences on the marine environment. Open-loop systems continuously discharge warm, acidic washwater that contains carcinogenic substances such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals. When released into the ocean, these substances pose a threat to aquatic wildlife, including threatened and critically endangered pods of resident killer whales that live off the coast of British Columbia.

The waters surrounding British Columbia's Vancouver Island are home to northern and southern resident killer whales (RKWs), which, respectively, are listed as threatened and endangered. This analysis estimates the amount and location of heavy fuel oil (HFO) carriage, HFO use, and washwater discharge from ships operating off the coast of British Columbia in three scenarios: ships fitted with scrubbers as of 2017, ships predicted to be fitted with scrubbers by 2020, and an extreme scenario where nearly all HFO-capable ships use scrubbers. These results were overlaid with the locations of RKW critical habitats to illustrate where washwater discharge could impact these threatened and critically endangered species.

We found that:

» In 2017, 30 scrubber-equipped ships emitted nearly 35 million tonnes of scrubber washwater. Cruise ships were responsible for 90% of these discharges.

» Approximately 10% of scrubber washwater discharges occurred within RKW critical habitats, even though these locales represent only 0.6% of the study area.

» Nearly 90% of all HFO carried in the study area passes through RKW critical habitats.

» Carriage of HFO is expected to fall nearly 90% from 2017 to 2020 due to the IMO's 2020 fuel sulfur regulation. However, HFO use and scrubber washwater discharges are expected to grow by 35% as more ships, particularly container ships, bulk carriers, and roll-on/roll off ferries, begin to use scrubbers.

» Cruise ships will account for two-thirds of HFO use and washwater discharges in 2020 despite the exponential growth in scrubber use in other ship types.

Without rules requiring closed-loop or zero-discharge operations, the use of open-loop or hybrid scrubbers operating in open-loop mode is expected to grow, increasing washwater pollution discharges which worsen water quality, and perpetuating the risk of an HFO spill. Using hybrid- or closed-loop scrubbers in zero-discharge mode would eliminate water pollution emissions from these systems but the risk of an HFO spill would remain. Using marine gas oil (MGO) inside the North American Emission Control Area (ECA) and very low sulfur fuel oil (VLSFO) outside would obviate the use of scrubbers but could still pose a residual fuel spill risk. While there will always be negative consequences in the event of a fuel oil spill, using only MGO would eliminate the need for scrubbers and eliminate the chances of a residual fuel spill.

INTRODUCTION

This report investigates the use and carriage of heavy fuel oil (HFO) and the discharge of washwater from exhaust gas cleaning systems (EGCS), also called "scrubbers," from ships operating in the North American Emission Control Area (ECA) off the coast of British Columbia, including in and near critical habitat for threatened and critically endangered resident killer whales (RKWs). Southern RKWs are critically endangered, with only 76 individuals remaining, and northern RKWs are threatened with 309 animals remaining. We consider three scenarios: status quo based on actual 2017 ship traffic observed by Automatic Identification System (AIS) data and output from the ICCT Systematic Assessment of Vessel Emissions (SAVE) model; year 2020 based on predicted scrubber uptake; and an extreme case scenario where most HFO-capable ships use open-loop scrubbers. For each scenario, we map HFO carriage and open-loop scrubber washwater discharge, estimate total HFO carriage, HFO use, and washwater discharge within RKW critical habitat, and discuss the potential impacts on these animals.

BACKGROUND

The British Columbia coast is home to a biologically diverse ecosystem as well as busy seaports. Shipping traffic is dense in this area, as shown in Figure 1. Many ships take the Juan de Fuca Strait, the large channel separating Vancouver Island from the continent, to reach Vancouver or travel south through Puget Sound to reach Seattle. Cruise ships make their way through the smaller, scenic Northern Passage, including the Johnstone strait, to Alaska.

British Columbia's waters fall within the North American ECA. Inside the ECA, ships either use lower sulfur fuels, such as marine gas oil (MGO), or high-sulfur fuels, such as HFO, with an EGCS.[1] Outside of the ECA, ships can use HFO without a scrubber. Nearly 2,500 of the 3,000 ships operating in the ECA in 2017 were capable of using HFO. Thirty of them used HFO with a scrubber. Ships with scrubbers use HFO at all times but scrub the exhaust when they enter the ECA. Ships without scrubbers use MGO in the ECA but keep HFO on board so they can use it once they exit the control area.

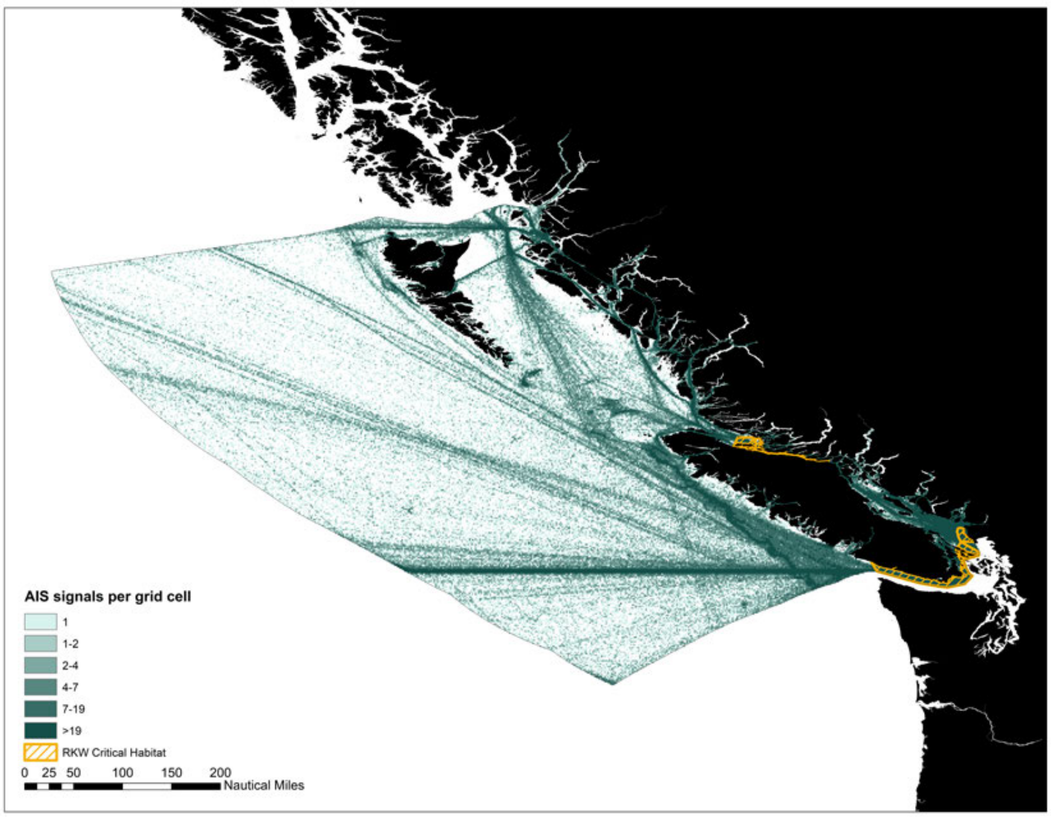

Figure 1. 2017 ship traffic in the Canadian portion of the North American ECA off the coast of British Columbia.

1 California does not allow the use of EGCS to comply with the 0.1% sulfur limit in state waters (out to 24 nautical miles) and China, Singapore, and Fujairah and several other ports have forbidden the use of open-loop scrubbers over concerns that scrubber washwater effluent is harmful to the environment

HEAVY FUEL OIL

Heavy fuel oil, also referred to as residual fuel, is extremely viscous leftover material from the oil refining process. It is the dominant fuel used by the marine sector due to its wide availability and cheap price, accounting for more than 80% of fuel used (Comer et al., 2017a). When burned, HFO releases greenhouse gases, short-lived climate pollutants such as black carbon, and air pollutants. It contributes to ambient fine particulate matter ($PM_{2.5}$) and ground-level ozone that harm human health by contributing to respiratory infections, cardiovascular disease, and lung cancer. Unlike other fuels, HFO does not evaporate but instead emulsifies in the water. This creates a mixture that is much larger than the original volume spilled, and one that is nearly impossible to completely clean up (Comer, 2019). Because HFO persists in the marine environment, it poses a long-term threat to aquatic wildlife in the event of a spill.[2]

EXHAUST GAS CLEANING SYSTEMS: "SCRUBBERS"

There are three types of scrubbers used on ships: open-loop, closed-loop, and hybrid. According to DNV-GL, open-loop scrubbers are the most popular among the three, making up 80% of the current market, followed by hybrid at 18%, with the remaining scrubbers being closed-loop or unknown (DNV GL, 2019). Open-loop scrubbers use continuously pumped-in seawater as an alkaline solution to dissolve sulfur oxide (SO_X) emissions. The washwater effluent is optionally treated to remove solids and raise pH before being discharged back into the ocean. If solids are stored as sludge on board, they are retained for shoreside disposal (Figure 2).

Closed-loop scrubbers, which use a freshwater and caustic soda alkaline solution, can operate in a zero-discharge mode or allow small, but potentially still contaminated, amounts of "bleed-off" water to be discharged overboard (Figure 3). Both sludge and bleed-off water can be stored on board and discharged shoreside. We are not aware of any prohibition on discharging bleed-off water to the sea, but IMO guidelines suggest that sludge residues should not be discharged at sea or burned on board and that residue disposal should be recorded in an EGC log. Hybrid scrubbers can operate in open-loop or closed-loop mode. The circulation pump in a hybrid system can be switched from seawater to a freshwater reservoir onboard and discharge can be routed from overboard to the circulating tank (American Bureau of Shipping, 2018).

2 For more information on the prevalence of HFO use in the shipping sector, see Comer et al. (2017a; 2017b); for commentary on the risks of HFO, see Comer and Olmer (2016).

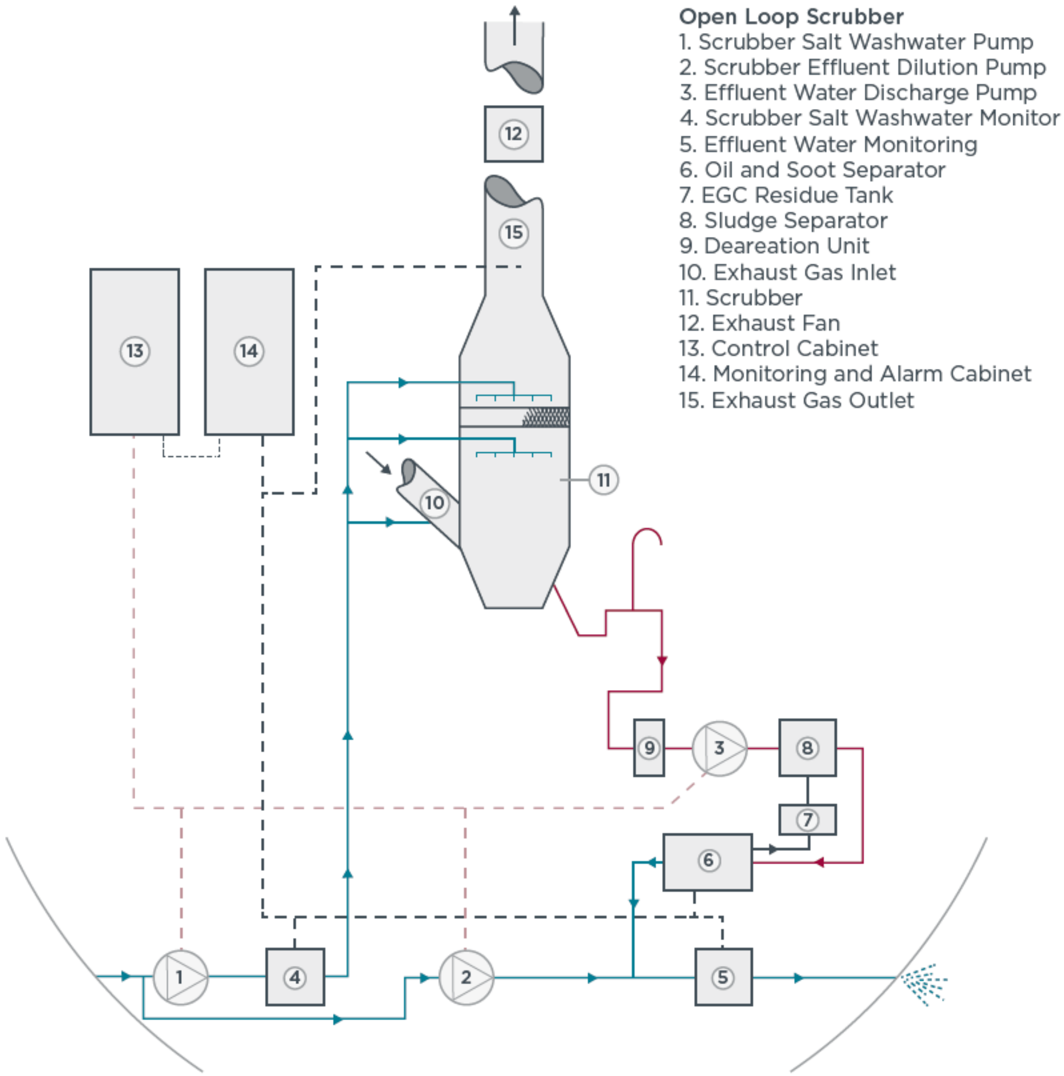

Figure 2. Open-loop scrubber design (Adapted from EGCSA, 2019)

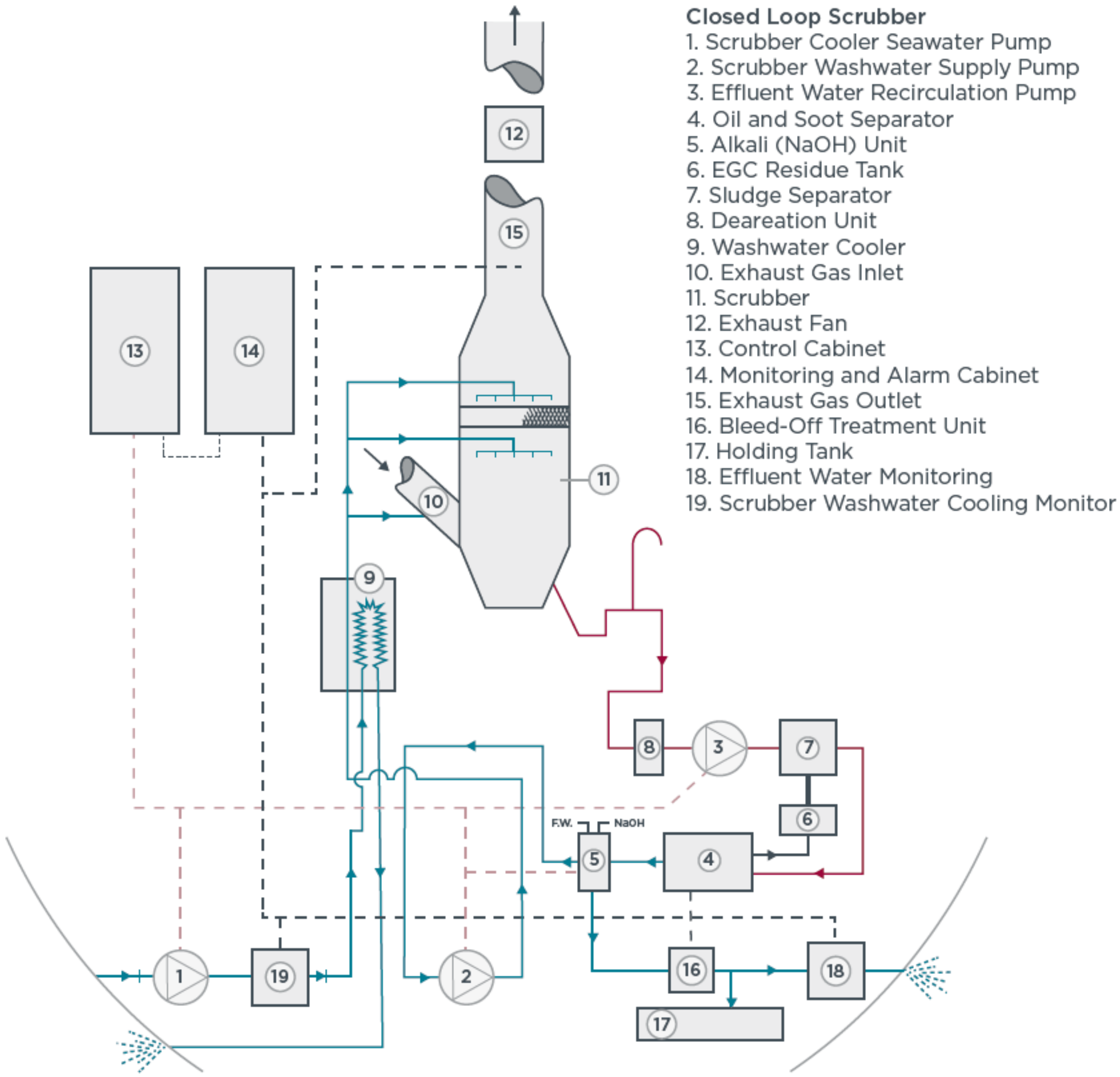

Figure 3. Closed-loop scrubber design (Adapted from: EGCSA, 2019)

Scrubber washwater effluent can contain heavy metals, polycyclic aromatic hydrocarbons (PAH), nitrates, sulfates, and particulate matter. Washwater can also be more acidic and warmer than ambient water. Exposure to washwater can harm aquatic organisms (Koski, Stedmon, & Trapp, 2017; Magnusson, Thor, & Granberg, 2018), and disruptions early in the food web, such as to zooplankton, can lead to negative impacts throughout the ecosystem. Heavy metals and PAHs are persistent in the marine environment and can accumulate in sediment which negatively affects bottom-feeders (Endres et al., 2018). Fish can suffer liver damage and reduced fertility even when exposed to even low PAH concentrations (Lange, Markus, & Helfst, 2015). Additionally, nitrates can cause an increase in pelagic phytoplankton and an increased risk of eutrophication in the summer months when algal bloom and cruise ships schedules overlap (Endres et al., 2018). Low pH and heavy metals can also act synergistically, with lower pH changing the solubility of heavy metals and in some cases leading to increase toxicity (Koski, Stedmon, & Trapp, 2017).[3]

The IMO developed guidelines in resolution MEPC.259(68) to ensure that EGCSs provide SO_x reductions that are equivalent to using compliant fuel. They recommend that the ship operator continuously monitor and record pH, PAH concentrations, turbidity, and temperature when the scrubber is operated in ports, harbors, or estuaries. The guidelines also include discharge limits for selected pollutants. Because these are guidelines, the discharge limits are not mandatory. However, flag states and classification societies may insist that EGCSs meet these limits and comply with parameters in the guidelines before a scrubber is approved as an equivalent compliance option.

KILLER WHALES

Killer whales (*Orcinus orca*) are one of the most recognizable cetaceans and are the largest members of the dolphin family, Delphinidae. Considered one species, there are three ecotypes off the coast of British Columbia: northern resident killer whales (NRKW), southern resident killer whales (SRKW), and transient Biggs killer whales. All three ecotypes are separated by genetics, behavior, and dietary preferences. Transient whales prefer marine mammals such as harbor seals, while residents have a strong preference for salmonid fish. NRKWs and SRKWs have different genetics and engage in different behaviors. The populations overlap but are rarely seen interacting or interbreeding (Fisheries and Oceans Canada, 2018a). As of 2017, there were 309 NRKWs divided into pods of about 10 to 25 individuals; they are listed as threatened under the Canadian Species at Risk Act, or SARA (Government of Canada, 2002). There are fewer SRKWs, with only 76 individuals divided into three pods; they are listed as endangered by SARA (Government of Canada, 2002). RKWs are primarily found off the coast of British Columbia, including in long inlets, narrow channels, and deeper bays. SRKWs congregate near the southern Strait of Georgia in the summer to intercept migrating salmon (Fisheries and Oceans Canada, 2018a).

The Canadian Species at Risk Act defines and describes the critical habitat for RKWs, which for SRKWs includes the Juan de Fuca Strait, Boundary Pass, Salish Sea, the Haro Strait, and the southern section of the Georgia Strait. Although the SRKW critical habitat stops at the Canadian border, it technically includes transboundary areas of British Columbia and Washington State and expands into the Puget Sound according to the United States' Endangered Species Act (ESA) definition of SRKW critical habitat (NOAA Fisheries, 2019). The NRKW critical habitat is found primarily in the Johnstone Strait and expands to the Charlotte Strait. The beaches in this area are important for the beach rubbing behavior, an activity specific to the NRKWs. Both resident killer whale populations have vast ranges (Figure 4). Only critical habitat was considered in this analysis due to the confirmed presence of RKWs in these areas and because these locales are, as the name suggests, critical to conserving these species.

3 For additional information on scrubber washwater characteristics, see Endres et al. (2018), Koski et al. (2017), Lange, Markus, and Helfst (2015), Magnusson, Thor, and Granberg (2018), 't Hoen & Boer (2015), and US Environmental Protection Agency (2011).

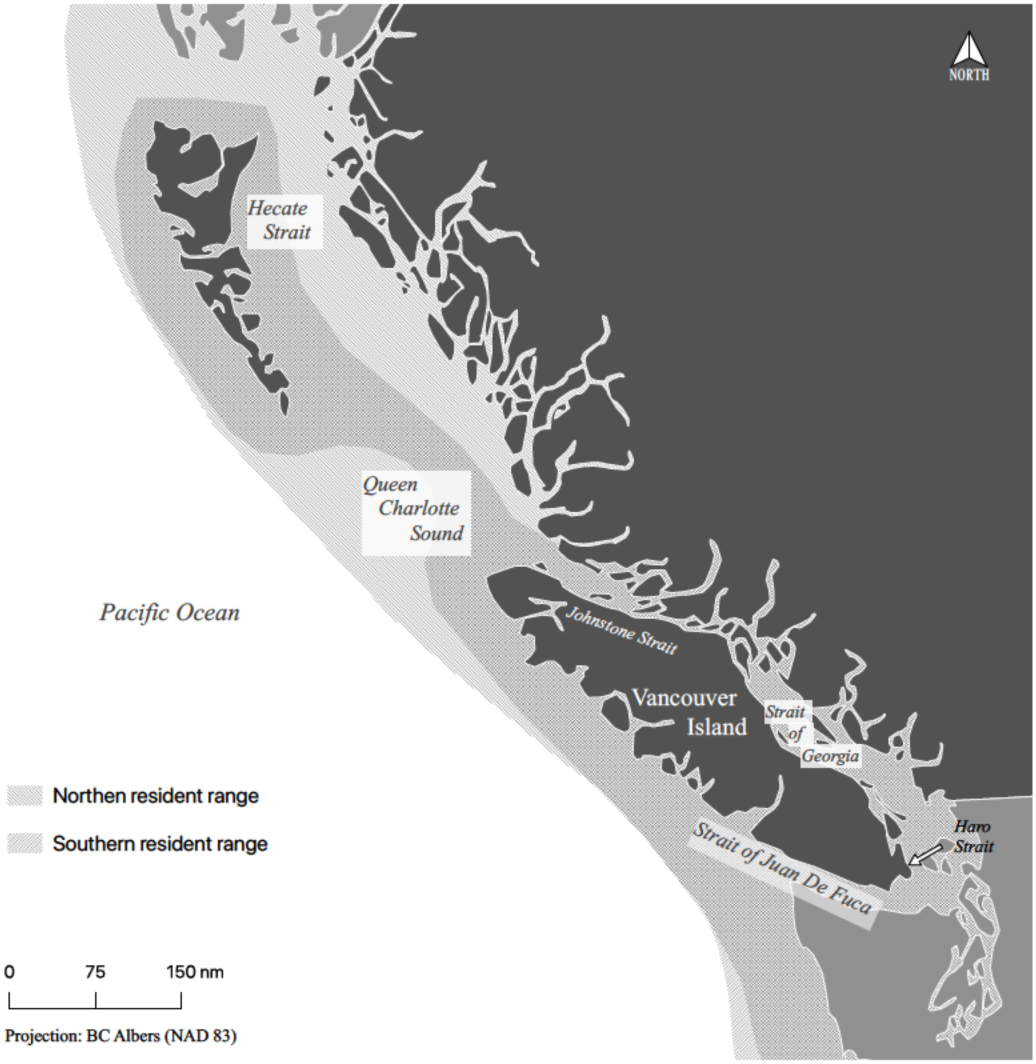

Figure 4. Resident killer whale ranges.

Note: Range shapefiles kindly provided by the British Columbia Cetacean Sightings Network

METHODOLOGY

IDENTIFYING SHIPS WITH SCRUBBERS

For our analysis, a database of ships with scrubbers was created by first identifying ships that were capable of using HFO and then searching through publicly available data to identify which ships have scrubbers installed. The sources confirming scrubber installation for each ship are included in the Appendix.

We found that of the 30 ships with scrubbers installed, 16 had open-loop scrubbers and 14 had hybrid scrubbers. It is possible that some ship operators sometimes voluntarily operate in closed-loop mode. That said, more than half of the ships studied used open-loop scrubbers that do not have a "closed loop" option. We are not aware of any prohibitions on operating in open-loop mode in the study area and operating in closed-loop mode generates additional labor, operating, maintenance, and disposal costs. Without mandatory prohibitions on operating in open-loop mode, we assume that ships with hybrid scrubbers operate them in open-loop mode at all times. While it is possible that we are overestimating washwater effluent by this assumption, this is mitigated by the following: (1) the study area is large, with much of the HFO use and discharge away from land; (2) we assume a normalized washwater effluent discharge rate consistent with IMO guidelines—actual rates could be lower or higher and we have seen rates more than two times greater than our assumption; (3) only half of the scrubber-equipped ships in 2017 had hybrid systems, the rest were open loop; and (4) any decision to operate in closed-loop mode would be a company policy which could be reversed. Finally, if ships with hybrid scrubbers voluntarily operate in closed-loop mode within 3 nm of land, discharges elsewhere can make their way to near-shore areas through currents, wind, and waves.

ESTIMATING HFO CARRIAGE

In the 2017 scenario, we assume that all HFO-capable ships carried HFO on board. Ships with scrubbers burn HFO at all times and ships that are capable of burning HFO but do not have a scrubber will burn ECA-compliant fuel inside the ECA and HFO outside the ECA. Consistent with our previous work (e.g., Olmer, Comer, Roy, Mao, & Rutherford, 2017), we assume that the ship's bunker fuel tanks are 65% full at all times.

Beginning in 2020, we assume that only scrubber-equipped ships will carry HFO on board. Other HFO-capable ships will use very low sulfur fuel oil (VLSFO) that is <0.50% S by mass or MGO when they are outside of an ECA. Fuel choice will depend on shipowner/operator confidence in the quality of VLSFO and the relative price between different grades of fuel.

In the extreme scenario, we assume that most[4] HFO-capable ships use scrubbers and therefore all these ships carry HFO. This assumption results in slightly smaller estimates for HFO carriage compared to the 2017 "status quo" scenario. As we mentioned earlier,

4 There were a few HFO-capable ships from other ship types, such as fishing vessels, not represented in Table 1. These ship types are, so far, not installing scrubbers. We assume that will continue to be the case. Therefore, the extreme case assumes that most, but not all, HFO-capable ships install scrubbers.

in the 2017 status quo scenario we assumed that all HFO-capable ships carried HFO on board, including those without scrubbers, because they could use HFO when they are outside of ECAs.

ESTIMATING HFO USE

Within the study area, only ships equipped with scrubbers are allowed to burn HFO. For these ships, we estimated HFO use using ICCT's SAVE model, which combines AIS data with IHS ship characteristics data to estimate fuel consumption and emissions for every ship for every hour. Given that we know the location of each ship from the AIS data, we can also map fuel carriage, fuel consumption, and emissions. Olmer et al. (2017) provides a detailed methodology for the SAVE model.

The SAVE model estimates fuel consumption for each hour by first estimating the ship's power demands. For main engines, power demand is a function of ship speed. For auxiliary engines and boilers, power demand varies depending on whether the ship is cruising, maneuvering, anchored, or at berth. For each hour, SAVE estimates fuel consumption by multiplying the total power demand of the ship (main engines + auxiliary engines + boilers) by a CO_2 emission factor and then divides by a fuel-specific carbon factor to convert from CO_2 emitted to fuel consumption:

$$FC_{i,t} = \text{TED}_{i,t} \times \frac{\text{EF}_{CO_2}}{\text{C}_f}$$

$FC_{i,t}$ = fuel consumption for ship i over time t
$TED_{i,t}$ = total energy demand of ship i over time t in kWh
EF_{CO_2} = emission factor for CO_2 for a given fuel and engine combination in g/kWh
C_f = carbon factor for the fuel in g CO_2/g fuel

ESTIMATING SCRUBBER WASHWATER DISCHARGE

We estimated scrubber washwater discharges for open-loop scrubbers and hybrid scrubbers, which we assume are always operating in open-loop mode. We assume that exhaust gas from all onboard machinery is treated by the scrubber although, in practice, some ships will only treat their main engine exhaust, opting to use low-sulfur distillate fuels to power auxiliary machinery. In such instances, the total amount of exhaust flowing through the scrubber system would be reduced. Consequently, the amount of washwater discharged would also be lower.

Washwater discharges for each ship for each hour is estimated as follows:

$$D_{i,t} = \frac{TED_{i,t}}{1000} \times r$$

$D_{i,t}$ = washwater discharge of ship i over time t in tonnes
$TED_{i,t}$ = total energy demand of ship i over time t in kWh
r = normalized washwater discharge rate in tonnes per MWh

We assume a normalized washwater discharge rate (r) of 45 t/MWh, which is consistent with IMO guidelines for EGCSs in Resolution MEPC.259(68). Although this rate is identified by the guidelines as typical for open-loop scrubber systems, ships discharge washwater at variable flow rates depending on the specific scrubber system installed, the alkalinity of the scrubbing solution, exhaust flow, fuel sulfur content, and other parameters. Other studies have used average open-loop discharge rates of 100 t/MWh (German Federal Maritime and Hydrographic Agency, 2019). The pollutant discharge concentration limits in the IMO guidelines vary as a function of discharge rate such that the mass of pollutants discharged per MWh remains constant.

SCENARIOS

For this analysis, we modeled the following three scenarios:

Scenario 1: 2017 status quo. This scenario analyzes estimated scrubber washwater discharges in the study area in 2017, based on 2017 AIS data and publicly available scrubber installation records (see Appendix).

Scenario 2: 2020 predicted. In this scenario, we estimated scrubber washwater discharges in the study area in 2020, based on 2017 ship activity and trends in scrubber installations. We used DNV-GL (2019) Alternative Fuels Insight Scrubber Data, which tracks installations and orders of scrubbers. Table 1 shows estimates of the proportion of ships that will have open-loop or hybrid scrubbers installed in 2020, broken down by ship type. We assume that the same proportion of the British Columbia fleet will be equipped with scrubbers as the world fleet and that those ships will operate scrubbers in open-loop mode. Finally, we randomly selected ships on which to apply scrubbers and predicted 2020 scrubber washwater discharges by assuming that they, or a similar ship, would engage in the same activity in 2020 as they did in 2017.

Table 1. Proportion of global fleet with open-loop or hybrid scrubbers by ship type in 2020

Ship type	Proportion of ships
Bulk carrier	11%
Chemical tanker	5%
Container	15%
Cruise	69%
General cargo	1%
Oil tanker	7%
Roll-on/roll-off	26%
Vehicle carrier	4%

Source: DNV-GL (2019) and IHS (2018)

Scenario 3: Extreme case. In the final scenario, we estimated scrubber washwater discharges, based on 2017 ship activity, assuming all HFO-capable ships of all ship types represented in Table 1 had scrubbers installed and that all of them were operated in open-loop mode.

RESULTS

In this section, we first present information on ships that had open-loop or hybrid scrubbers installed in 2017. We then present HFO carriage and HFO use and associated scrubber washwater discharges under three scenarios: 2017 status quo; 2020 predicted; and an extreme case.

SHIPS WITH SCRUBBERS

Table 2 summarizes the number of ships using open-loop or hybrid scrubbers in open-loop mode in each scenario. Each scenario is described in more detail in this section.

Table 2. Number of ships using open-loop or hybrid scrubbers in open-loop mode.

			Ships with Scrubbers		
Ship type	Total ships (all fuel types)	HFO-capable ships	Scenario 1: 2017 Status quo	Scenario 2: 2020 Predicted	Scenario 3: Extreme case
Bulk carrier	1,446	1,446	1	159	1,446
Chemical tanker	118	118	0	6	118
Container	330	330	3	46	330
Cruise	44	32	23	23	32
General cargo	161	156	0	1	156
Oil tanker	91	90	0	6	90
Roll-on/roll-off	10	4	0	1	4
Vehicle carrier	193	193	3	8	193
Other ship types	657	63	0	0	0
Total	**3,050**	**2,432**	**30**	**250**	**2,369**

Scenario 1: 2017 Status quo.

In 2017, 3,050 ships operated within the Canadian portion of the North American ECA off the coast of British Columbia. Of those, 2,432 were HFO-capable and 30 had scrubbers installed.

For the 30 scrubber-equipped ships, 14 used hybrid scrubbers and 16 used open-loop; no ships used closed-loop scrubbers. Twenty-three of the 30 scrubber-equipped ships, or 77%, were cruise ships, followed by three container ships, three vehicle carriers, and one bulk carrier. Cruise ships have been early adopters of scrubber technology because they tend to spend more time in ECAs than other ship types. This results in faster payback periods and greater returns on investment for scrubber technologies than ships that only occasionally operate in ECAs.

Scenario 2: 2020 predicted.

In 2020, based on DNV-GL (2019) scrubber uptake statistics for 2020 for the global fleet, we predict that 250 ships operating in the study area will have scrubbers, the majority of which will be bulk carriers.[5] This reflects a trend towards more bulk carriers using scrubbers globally and the fact that nearly half of the ships operating in the study area in 2017 were bulk carriers. We also predict a large increase in container ships with scrubbers, up from three in 2017 to 46 in 2020. Some ship types that did not have scrubbers installed in 2017 are expected to by 2020, including chemical tankers, general cargo ships, oil tankers, roll-on/roll-offs, and vehicle carriers.

Scenario 3: Extreme case.

In this case, we assume that all of the HFO-capable bulk carriers, chemical tankers, container ships, cruise ships, general cargo ships, oil tankers, roll-on/roll-offs, and vehicle carriers we observed in the study area in 2017 installed scrubbers which operate in open-loop mode at all times. In total, this would equal 2,369 ships with scrubbers. Bulk carriers, container ships, general cargo ships, and vehicle carriers would see the most dramatic increases in the use of scrubbers.

HFO CARRIAGE

The maps in Figure 5 show the pattern of HFO carriage under each scenario. Figure 6 shows HFO carriage by ship type for each scenario.

5 Based on DNV-GL (2019) as of July 23, 2019. Note that, DNV-GL predicts that, globally, 69% of cruise ships will have either open-loop or hybrid scrubbers installed in 2020. In 2017, we observed that 77% of cruise ships in the study area had scrubbers; therefore, we assume that in 2020, the same number and proportion of cruise ships will have scrubbers installed as in 2017

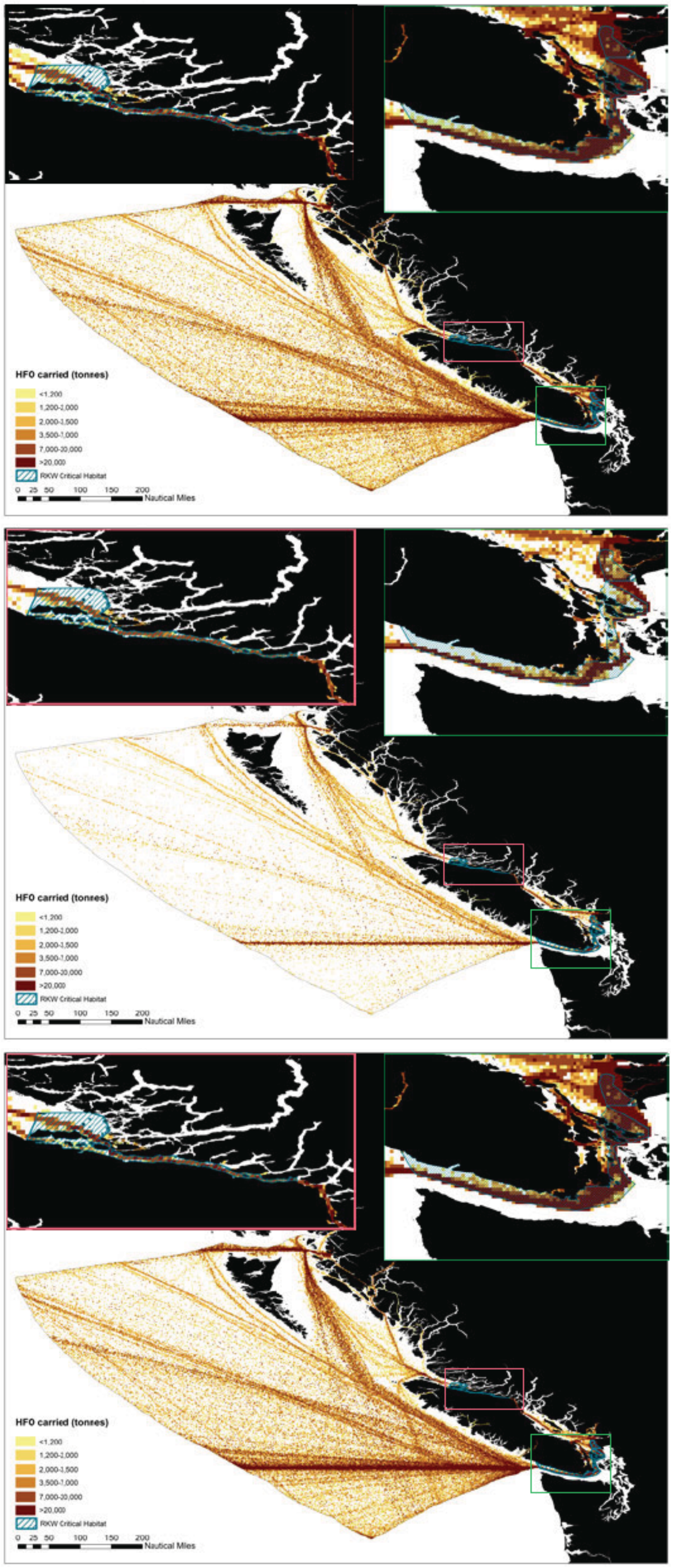

Figure 5. Heavy fuel oil carried in 2017 (top), 2020 (predicted, middle), and an extreme case (bottom), in tonnes

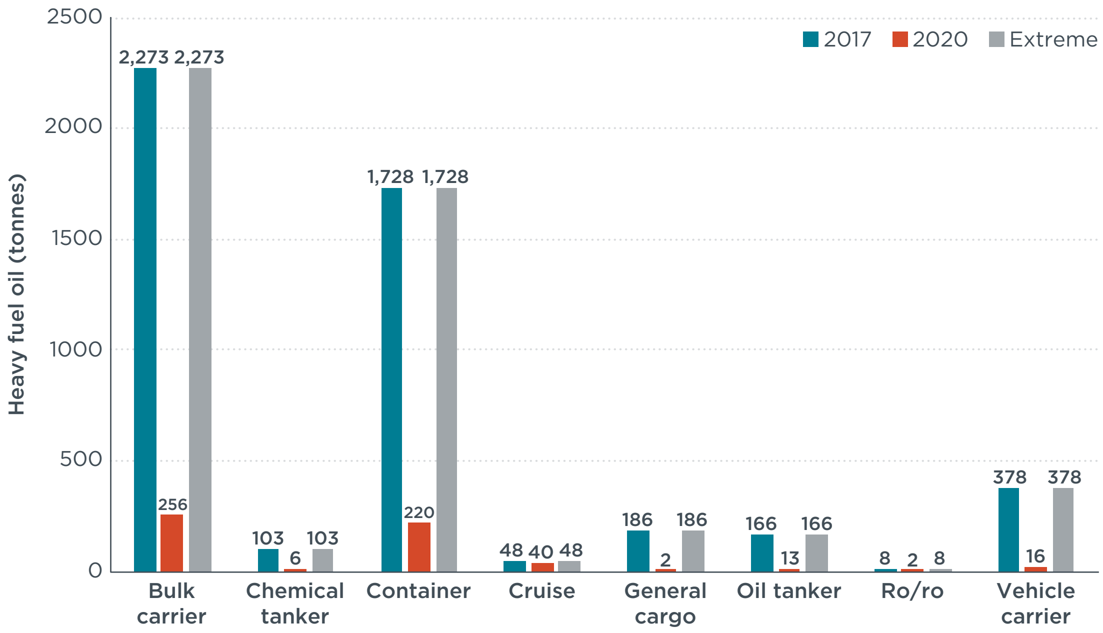

Figure 6. Heavy fuel oil carriage by ship type for each scenario.

In 2017, nearly five million tonnes of HFO were carried as fuel throughout the Canadian portion of the North American ECA off the coast of British Columbia, most of which (4.5 million tonnes) was also carried through RKW critical habitats at one time or another. We assumed that all HFO-capable ships carried HFO in 2017 for use outside of ECAs. Bulk carriers and container ships carried the most HFO on board in 2017 (Figure 6).

In 2020, we expect the amount of HFO carried on board ships to decrease by almost 90% to about half a million tonnes in the study area. HFO carriage in RKW habitats will also fall approximately 90%. Beginning in 2020, only scrubber-equipped ships will carry HFO on board. However, HFO-capable ships that do not use scrubbers may comply with IMO's 0.5% fuel sulfur limit by using VLSFO, which may be a blended fuel that contains HFO or that behaves like HFO when burned or spilled. Alternatively, ships may use MGO to comply with the limit. Fuel choice will depend on shipowner/operator confidence in the quality of VLSFO and the relative price between different grades of fuel. Like in the 2017 scenario, we expect bulk carriers and container ships to carry the most HFO fuel on board.

In the extreme scenario, most HFO-capable ships are assumed to use scrubbers and, therefore, would carry HFO on board at all times. Because few HFO-capable ships fall outside of the ship types we assume will use scrubbers, we estimate HFO carriage to be roughly the same for the status quo and extreme scenarios—about 5 million tonnes, with bulk carriers and container ships carrying the most fuel.

HFO USE AND WASHWATER DISCHARGE

The maps in Figure 7 show the pattern of washwater discharge under each scenario; the pattern for HFO use is similar.

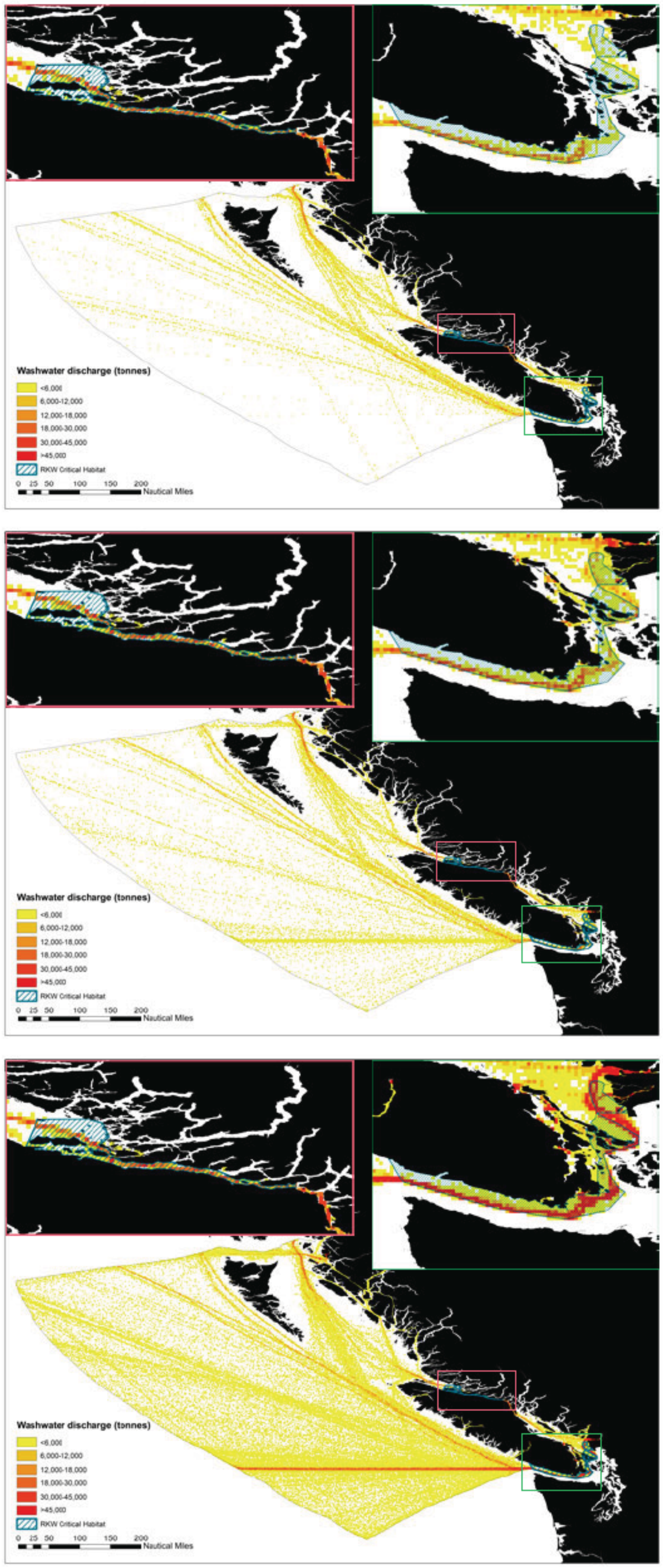

Figure 7. Washwater discharge in in 2017 (top), 2020 (predicted, middle), and an extreme case

Figure 8 shows HFO use and Figure 9 shows washwater discharges by ship type for each scenario.

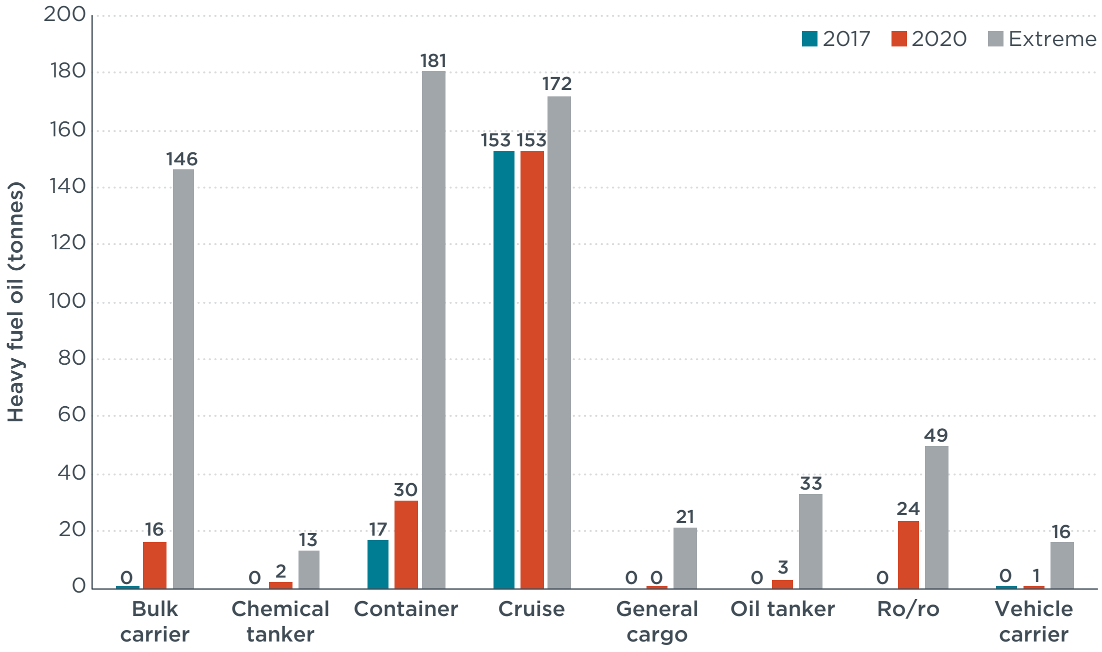

Figure 8. Heavy fuel oil use by ship type for each scenario.

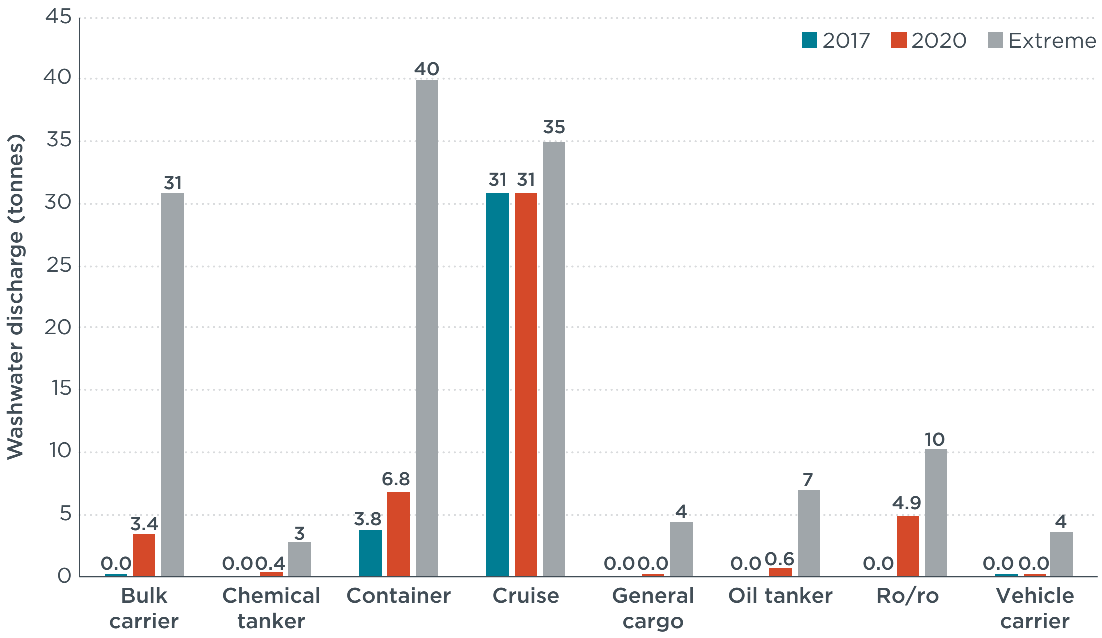

Figure 9. Washwater discharge by ship type for each scenario.

In 2017, ships used about 170 thousand tonnes of HFO in the study area. Total HFO use is expected to grow by 34% to 230 thousand tonnes in 2020 and, in an extreme case, by 270% to 630 thousand tonnes. As HFO use increases due to an increase in scrubber uptake, we expect more HFO to be used in the study area and within RKW critical habitats, leading to increases in washwater discharges.

In 2017, washwater discharges, totaled 35 million tonnes. About 10% of discharges occurred within RKW critical habitat, even though, geographically, these habitats represent only 0.6% of the study area. In 2017, HFO use and washwater discharges were mainly from cruise ships, with container ships a distant second (Figure 8). Cruise ships accounted for 23, or 77%, of the 30 ships with scrubbers in 2017. They emitted 31 million, or nearly 90%, of the 35 million tonnes of washwater discharged in the region (Figure 9). Cruise ships often sail through the Johnstone Strait, leading to high washwater discharges inside the northern RKW critical habitat. When cruises leave Victoria, washwater discharges occur within the southern RKW critical habitat.

By 2020, we predict a 35% increase in total scrubber washwater discharges to about 47 million tonnes. Washwater discharges within RKW critical habitat is expected to grow by 45% to nearly 5 million tonnes by 2020. We predict HFO use and washwater discharges to increase from 2017 to 2020 for container ships and bulk carriers (Figure 9). Additionally, we expect some ship types that were not outfitted with scrubbers in 2017 to start using them, including roll-on/roll-offs, oil and chemical tankers, general cargo ships, and others.

Under an extreme scenario, washwater discharges nearly quadruple from 2017, reaching more than 130 million tonnes in total, with 18 million tonnes in RKW critical habitat. Container ships, cruise ships, and bulk carriers discharge the greatest quantities of washwater in the extreme case.

DISCUSSION

As 2020 approaches, some ships will stop carrying and using HFO to comply with IMO's 0.5% fuel sulfur limit, while others will use scrubbers that enable them to continue to burn HFO. Without rules requiring closed-loop or zero-discharge operations, we expect the use of open-loop scrubbers—and hybrid scrubbers operating in open-loop mode—to grow, increasing washwater pollution discharges and perpetuating the risk of an HFO spill.

Additionally, even with scrubbers, ships will continue to emit air and climate pollution emissions such as particulate matter, sulfur oxides, nitrogen oxides, black carbon, and carbon dioxide. As a consequence, ships with scrubbers will continue to pose both direct and indirect risks to aquatic wildlife, including threatened and endangered species such as RKWs. Unfortunately, British Columbian killer whales are already considered the most contaminated marine mammal species in the world, as measured by polychlorinated biphenyl (PCB) concentrations, which increases their risk for toxic effects (Ross, Ellis, Ikonomou, Barrett-Lennard, & Addison, 2000).

HEAVY FUEL OIL SPILL RISKS

Carrying HFO in ships' fuel tanks perpetuates the risk of an HFO spill. In addition to the economic costs of a spill, there are ecological costs (Deere-Jones, 2016). Oil spills directly impact aquatic wildlife through ingestion, absorption, and– in the case of marine mammals—inhalation of fumes. Additionally, oil spills can have indirect effects by harming the food web and forcing wildlife to search for food in new locations (Ober, 2010).

WASHWATER CONTAMINANTS

Open-loop scrubbers and hybrid scrubbers in open-loop mode emit acidic washwater that is warmer than ambient sea water and contains heavy metals, PAHs, suspended particulate matter, and nitrates, all of which can harm RKWs. While the IMO has published guidelines in resolution MEPC.259(68) that contain continuous discharge limits for pH, PAH, turbidity, nitrates, and temperature for washwater, no scientific justification is given for these limits. These limits are not strictly mandatory, although flag states and classification societies can insist that these limits be achieved by scrubbers that are installed.

Polycyclic aromatic hydrocarbons and heavy metals are of particular concern for marine mammals. Even if ships discharge low concentrations of these contaminants, they accumulate in the environment and bioaccumulate in the food web. Over time, pollutant concentrations will increase, especially in shallow, coastal areas where dilution is limited and vessel traffic is high (Endres et al., 2018) Exposure to PAHs and heavy metals has been linked to negative health outcomes for other marine mammal species, such as beluga whales and pinnipeds. These effects are generalized to killer whales due to the similar physiological processes of marine mammals (Ross, 2000). Additionally, synergistic effects of exposure to scrubber washwater could be important. Researchers at IVL Swedish Environmental Research Institute suggested the combined effects of exposure to washwater contaminants on zooplankton, which form the basis of the food web for many species, may be dramatically different than the effect of exposure to only one pollutant (Magnusson et al., 2018).

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons are produced by incomplete combustion of fossil fuels, such as HFO. When ships use HFO with scrubbers, larger PAHs will bind to particulates in the exhaust and smaller PAHs go into the washwater. Unfortunately, smaller PAHs are more toxic to marine life (Marsili et al., 2001). A detailed assessment of PAH discharge was beyond the scope of this analysis, but we can estimate the maximum "allowable" discharges under the IMO guidelines. The IMO guidelines set a PAH limit of 50 µg/L when the washwater discharge rate is 45 t/MWh. Based on our results, we estimate that 1,740 kg of PAHs were discharged in the study area in 2017, almost 10% of which, or 165 kg, was emitted within RKW habitat. We expect this to grow to 2,360 kg in the study area, with 10% (240 kg) in RKW habitat in 2020. In the extreme scenario, one could see 6,700 kg emitted in the study area, with 880 (13%) in RKW critical habitat.

PAHs are persistent organic pollutants, which means they resist biodegradation. When RKWs eat contaminated fish, PAHs are stored in the RKWs' fat reserves, including their protective blubber layer (Formigaro et al., 2014). When RKWs draw upon their fat reserves for energy, problems can occur. PAHs damage DNA, which can cause cancer (Munoz & Albores, 2011). On the east coast of North America in the St. Lawrence estuary, high PAH concentrations in Beluga whales corresponded to higher rates of digestive tract cancers (Martineau et al., 2002).

Heavy metals

Heavy metals are naturally occurring elements found in the earth's crust. Some heavy metals are essential nutrients at lower concentrations, such as copper, zinc, and iron, while others, such as lead, mercury, and cadmium, are toxic in any amount. Heavy metals are neither biodegradable nor water soluble. They can bioaccumulate in tissues of animals, including the fish that RKWs eat. While Orcas, including RKWs, have proteins that bind and detoxify mercury, these capabilities are limited, and when mercury levels are high, they can bypass the proteins and cause toxicity (Buckman et al., 2011).

Heavy metals accumulate in the liver, bone marrow, and kidneys (Dosi, 2000). Stored heavy metals are released during pregnancy, lactation, migration, and when food is scarce (Marsili et al., 2001). With Chinook salmon fisheries declining, especially in southern British Columbia waters, nutritional stress is causing RKWs to tap into their blubber resources, releasing these stored pollutants (Fisheries and Oceans Canada, 2018b). Exposure to toxic compounds including PAHs and heavy metals were coincident with cancers in populations of beluga whales in the St. Lawrence River (Guise, Lagacé, & Béland, 1994). Besides carcinogenic effects, chronic intake of heavy metals suppresses the immune system (Kakuschke & Prange, 2007.). Exposure to copper, mercury, and lead has been associated with reproductive dysfunction, difficulty locating prey, and poor metabolism in marine mammals (Jakimska, Konieczka, Skóra, & Namiesnik, 2011).

FUTURE WORK

This analysis estimates HFO carriage, HFO use, and scrubber washwater discharges. While we know open-loop scrubbers continuously discharge, hybrid systems can operate in closed-loop mode. Future work could further investigate when and where ships could opt for closed-loop operations, including near shore. In addition, the impacts of voluntarily switching to compliant fuels or operating hybrid scrubbers in closed-loop mode near shore and in RKW critical habitats could be modelled. However, washwater discharges outside these areas can make their way inside through currents, wind, and waves.

Our results show where HFO was used and carried and where washwater was discharged, but it does not show the dispersal areas of an HFO spill or washwater discharge. The impacts of an HFO spill on RKWs would be better understood if the HFO carriage results were fed into a spill dispersion model. Likewise, RKW washwater exposure could be better estimated by feeding the washwater discharge location data into a water dispersion mode. Lastly, additional research on the impacts of scrubber washwater discharges on the food web is warranted, particularly on Chinook salmon, the RKWs main food source.

CONCLUSION

This study investigates HFO carriage, HFO use, and scrubber washwater discharges from ships in the Canadian portion of the North American ECA off the coast of British Columbia, including in and near critical habitat for threatened and critically endangered RKWs. We considered three scenarios: 2017 status quo based on actual HFO and scrubber use; 2020 based on predicted HFO and scrubber use; and an extreme case where most HFO-capable ships used scrubbers.

Resident killer whales, which are already facing environmental stressors, are currently exposed to contaminated scrubber washwater discharges. Ships are using hundreds of thousands of tonnes of HFO, resulting in millions of tonnes of scrubber washwater discharges, 10% of which is emitted directly in RKW critical habitats. In addition, RKWs are in danger of being exposed to an HFO spill from ships carrying HFO on board.

Unfortunately, threats to aquatic wildlife, such as RKWs, are expected to grow as more ships install scrubbers in order to comply with IMO's 2020 fuel sulfur regulations. While we expect HFO carriage to drop by almost 90% in 2020 as more ships use VLSFO to comply with IMO's fuel sulfur regulations, we predict HFO use and scrubber washwater discharges will increase about 35% from 2017 levels. In an extreme scenario, where nearly all HFO-capable ships use scrubbers, HFO carriage is estimated to be the same as in 2017, but HFO use and washwater discharges increase nearly four-fold from 2017 levels. In all scenarios, nearly 90% of all HFO carried in the study area passes through RKW critical habitats.

Cruise ships were responsible for the most HFO use and scrubber washwater discharge in 2017. We predict this will still be true in 2020, even though scrubber uptake by other ship types is expected to grow exponentially. In the extreme scenario, container ships use the most HFO and emit the most washwater, but cruise ships are not far behind. Cruise ships currently travel through the Johnstone Strait, which is also critical habitat for the northern RKWs. As other ship types use scrubbers, impacts on southern RKWs are expected to grow. The Juan de Fuca Strait, Georgia Strait, and Haro Strait have the highest ship density in the region and fall within SRKW critical habitat. As washwater discharges increase, so will acidic water, suspended particulate matter, nitrates, PAHs, and heavy metals.

Without rules requiring closed-loop or zero-discharge operations, we expect the use of open-loop scrubbers and hybrid scrubbers operating in open-loop mode to grow, increasing washwater pollution discharges that worsen water quality and perpetuating the risk of an HFO spill. Using hybrid or closed-loop scrubbers in zero-discharge mode would eliminate water pollution from these systems but maintain the risk of an HFO spill. Using MGO inside the North American ECA and VLSFO outside would obviate the use of scrubbers but could still pose a significant risk when spilled. While there will always be negative consequences in the event of a fuel oil spill, using MGO at all times would eliminate the risks of an HFO or VLSFO spill and remove altogether the need for scrubbers.

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APPENDIX: SHIPS WITH SCRUBBERS IN THE STUDY AREA IN 2017

Ship Name	IMO number	Ship Type	Scrubber Type	Source
Matson Anchorage	8419142	Container	Hybrid	Brehmer (2017)
Matson Tacoma	8419154	Container	Hybrid	Brehmer (2017)
Matson Kodiak	8419166	Container	Hybrid	Brehmer (2017)
Grand Princess	9104005	Cruise	Open loop	Alaska DEC (2018) CAO-20180701- 1882007070
Disney Wonder	9126819	Cruise	Hybrid	Sanders (2012)
Volendam	9156515	Cruise	Open loop	Alaska DEC (2018) CAO-20180605-1880073526
Zaandam	9156527	Cruise	Open loop	Alaska DEC (2018) CAO-20180613- 1880619899
Amsterdam	9188037	Cruise	Open loop	Alaska DEC (2018) CAO – 20180621- 1881189247
Celebrity Millennium	9189419	Cruise	Hybrid	Alaska DEC (2018) CAO-20180704 - 1882276275
Celebrity Infinity	9189421	Cruise	Hybrid	Alaska DEC (2018) CAO – 20180624- 1881375564
Golden Princess	9192351	Cruise	Open loop	Alaska DEC (2018) CAO-20180530- 1879720692
Star Princess	9192363	Cruise	Open loop	Alaska DEC (2018) CAO-20180607- 1880301750
Radiance of The Seas	9195195	Cruise	Hybrid	Alaska DEC (2018) CAO-20180610- 1880421643
Norwegian Sun	9218131	Cruise	Hybrid	Norwegian Cruise Line (2017)
Oosterdam	9221281	Cruise	Open loop	Andrews (2016)
Carnival Legend	9224726	Cruise	Open loop	Alaska DEC (2018) CAO-20180703- 1882100843
Coral Princess	9229659	Cruise	Open loop	Alaska DEC (2018) CAO-20180605- 1880142743
Noordam	9230115	Cruise	Open loop	Alaska DEC (2018) CAO-20180603- 1880002946
Island Princess	9230402	Cruise	Open loop	Alaska DEC (2018) CAO-20180529- 1879623355
Carnival Miracle	9237357	Cruise	Open loop	Brehmer (2017)
Norwegian Jewel	9304045	Cruise	Hybrid	Norwegian Cruise Line (2016)
Emerald Princess	9333151	Cruise	Open loop	Alaska DEC (2018) CAO-20180623- 1881279445
Norwegian Pearl	9342281	Cruise	Hybrid	Alaska DEC (2018) CAO-20180512- 1878516656
Eurodam	9378448	Cruise	Open loop	Alaska DEC (2018) CAO-20180623-1881279434
Nieuw Amsterdam	9378450	Cruise	Open loop	Alaska DEC (2018) CAO-20180524-1879375472
Ruby Princess	9378462	Cruise	Open loop	Alaska DEC (2018) CAO-20180602- 1879927959
Thermopylae	9702443	Vehicle	Hybrid	The Maritime Executive (2016)
Thalatta	9702455	Vehicle	Hybrid	The Maritime Executive (2016)
Theben	9722302	Vehicle	Hybrid	Wärtsilä (2016)
Nadeshiko	9757785	Bulk carrier	Hybrid	Ship Technology. (2016)

THE INTERNATIONAL COUNCIL
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NOVEMBER 2020

Air emissions and water pollution discharges from ships with scrubbers

Bryan Comer, PhD, Elise Georgeff, and Liudmila Osipova, PhD

ICCT CONSULTING REPORT

ACKNOWLEDGEMENTS

We thank Environment and Climate Change Canada for funding this analysis. Thank you also to Environment and Climate Change Canada staff for reviewing earlier versions of this report.

International Council on Clean Transportation
1500 K Street NW Suite 650
Washington DC 20005 USA

communications@theicct.org | www.theicct.org | @TheICCT

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Ships use scrubbers to comply with fuel sulfur standards by removing sulfur dioxide from the exhaust instead of using lower sulfur but more expensive fuels. Instead, ships with scrubbers can continue to use cheaper high-sulfur heavy fuel oil (HFO). The International Maritime Organization (IMO) allows the use of scrubbers as an equivalent compliance option because they are expected to reduce sulfur dioxide emissions by the same, or more, as using compliant fuels. However, when considering the total air pollution consequences of scrubbers, they may not be equivalent to using lower-sulfur fuels, such as marine gas oil (MGO). Additionally, while scrubbers are effective at reducing sulfur dioxide, the sulfur and other contaminants removed from the exhaust gas—including carcinogens such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals—are dumped overboard in the form of washwater, also called discharge water. This happens even with so-called “closed-loop” scrubbers.

In this study, we estimated air and water emission factors for ships using HFO with scrubbers compared to other fuels based on the available literature and the methods of the *Fourth IMO Greenhouse Gas Study*. Regarding air emissions, we found that using scrubbers can substantially reduce sulfur dioxide emissions but carbon dioxide, particulate matter, and black carbon emissions were higher when using HFO with a scrubber than using MGO. For water pollutants, we found that scrubber discharges usually comply with IMO guidelines; however, compliance does not guarantee that scrubber discharges are safe. We found that all scrubbers (open-loop, closed-loop, and hybrid) discharge water that is more acidic and turbid than the surrounding water. Additionally, scrubbers emit nitrates, PAHs, and heavy metals, all of which can negatively affect water quality and marine life. Within Canada, this includes scrubber discharges in the Great Lakes, as well as British Columbia and the St. Lawrence Estuary, where endangered species like the Southern Resident killer whales and belugas already suffer from high levels of contamination, including from PAHs and heavy metals.

Based on this analysis, the ICCT makes the following recommendations. We recommend individual governments continue to take unilateral action to restrict or prohibit scrubber discharges from both open-loop and closed-loop systems. We also recommend that the IMO focus on harmonizing rules for scrubber discharges including where, when, and even if those discharges should be allowed, and to do so with urgency. The IMO should consider prohibiting the use of scrubbers as a compliance option for new build ships and work to phase out scrubbers installed on existing ships. This is because we found that using HFO with scrubbers is not equivalently effective at reducing air pollution compared to using lower sulfur fuels, such as MGO. Additionally, scrubbers of all kinds (open, closed, and hybrid) directly contribute to ocean acidification and water pollution, whereas lower sulfur fuels do not. Until then, we recommend that individual countries, including Canada, take immediate actions to protect their air and waters from scrubber emissions and discharges. These actions could include one or both of the following: (1) an immediate prohibition on using scrubbers to comply with the Canadian portion of the North American ECA because they are not equivalently effective at reducing air pollution as ECA-compliant fuels; (2) an immediate prohibition on all scrubber discharges in Canadian ports, internal waters, and territorial seas because they contribute to acidification and water pollution that can negatively affect marine life.

INTRODUCTION

In this report, the International Council on Clean Transportation (ICCT) provides expert advice to Environment and Climate Change Canada to enable them to update their Marine Emission Inventory Tool such that air and water pollution discharges from ships equipped with exhaust gas cleaning systems (EGCSs), also known as "scrubbers," can be estimated for ships operating in Canadian waters.

BACKGROUND

Ships use scrubbers as a way to comply with regional and global fuel sulfur standards by removing sulfur dioxide (SO_2) from the exhaust rather than using lower sulfur fuels. In the North American Emission Control Area (ECA), the maximum allowable fuel sulfur content is 0.10% by mass. The ECA extends 200 nautical miles from the U.S. and Canadian coasts and includes all Canadian waters south of 60°N latitude. The American and Canadian Arctic regions are not covered by the ECA. Outside ECAs, the maximum allowable sulfur content for marine fuels is 0.50% as of January 1, 2020. Before 2020, the maximum allowable sulfur content was 3.50%. This tightening of the global fuel sulfur cap drove dramatic increases in scrubber installations, and the rapid uptake of scrubber installations and orders in the lead-up to 2020 is illustrated in Figure 1.

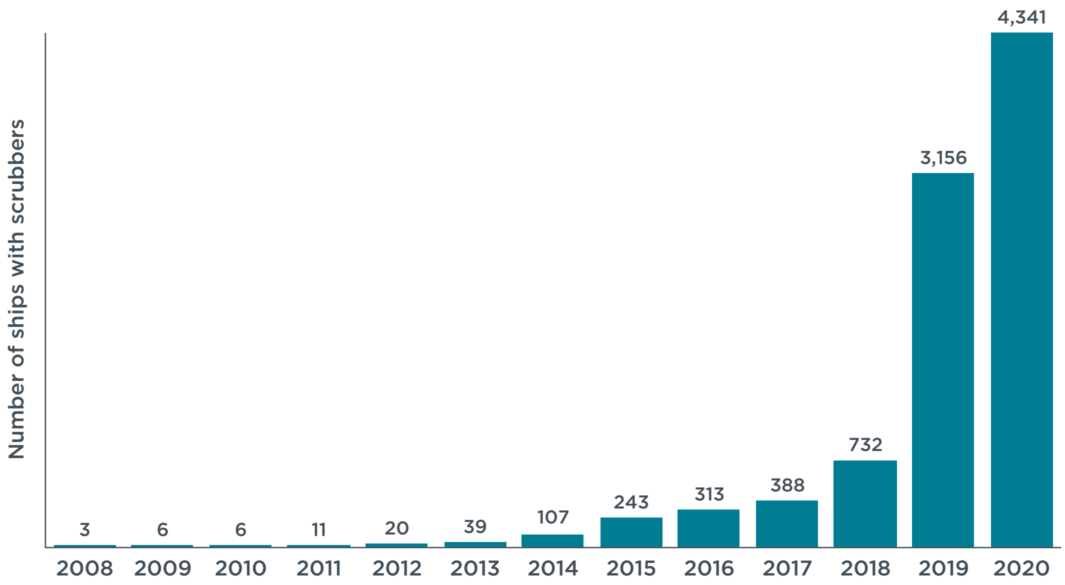


Figure 1. Number of ships with scrubbers by year. Source: DNV GL (2020)

While scrubbers are effective at reducing SO_2, the sulfur and other contaminants removed from the exhaust gas—including carcinogens such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals—are dumped overboard in the form of washwater, also called discharge water. Many of these contaminants in the washwater, including heavy metals and many PAHs, do not biodegrade and therefore amass in the environment and the food web. This makes these pollutants of particular concern for marine mammals. When marine mammals are exposed to these contaminants, usually through their food, the contaminants accumulate in their organs or are stored in their fat reserves. In lean times when food is scarce, or during pregnancy, the fat reserves are used, re-exposing the animal to the contaminants. Heavy metals, which are known to bioaccumulate in the liver, bone marrow, and kidneys in marine mammals, have been linked to carcinogenic effects and immune suppression in marine mammals (Dosi, 2000; Kakuschke & Prange, 2007). On the east coast of North America in the St. Lawrence estuary system, high PAH concentrations in beluga whales corresponded with higher rates of digestive tract cancers and tumor production (Guise, Lagacé, & Béland, 1994; Martineau et al., 2002). On the west coast, the endangered Southern Resident killer whales, found in the inlets and sounds of British Columbia, have a population critically at risk with only 72 individuals remaining in 2020, according to the U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries Department (NOAA Fisheries, 2020). PAHs and trace metals are listed as direct impacts to the species in the Recovery Strategy in their Species at Risk Act designation, which notes that they are likely to be the most contaminated mammals in the world (Government of Canada, 2011; Ross, Ellis, Ikonomou, Barrett-Lennard, & Addison, 2000).

Georgeff, Mao, and Comer (2019) found that, in 2017, 30 scrubber-equipped ships emitted nearly 35 million tonnes of scrubber discharge water off the coast of British Columbia, including in and near critical habitats for threatened and endangered Northern and Southern Resident killer whales. Cruise ships were responsible for 90% of these discharges. The paper predicted that the International Maritime Organization (IMO) 2020 global fuel sulfur cap would result in 47 million tonnes of scrubber discharges in that area in 2020 as more ships, particularly container ships, bulk carriers, and roll-on/roll-off ferries, begin to use scrubbers. This figure includes ships that use open-loop scrubbers, which continuously discharge contaminated washwater, and from hybrid scrubbers than are operated in open-loop mode. No ships used closed-loop scrubbers in that area. Forthcoming research from the ICCT will also show that in addition to discharges off Canada's west coast, ships are also using scrubbers on the east coast, including in the St. Lawrence estuary, home to endangered beluga whales (Osipova, Georgeff, & Comer, forthcoming).

Some ships are using closed-loop scrubbers or hybrid scrubbers in closed-loop mode, mainly when operating near shore or in port. Closed-loop scrubbers recirculate the washwater, but a small volume of bleed-off water is still emitted. Unlike open-loop systems, closed-loop systems store scrubber sludge (also called residuals) on board for on-land disposal. Although closed-loop scrubbers can operate in zero-discharge mode for short periods (Kjølholt, Aakre, Jürgensen, & Lauridsen, 2012), they most often emit highly concentrated and highly contaminated bleed-off, making "closed loop" a bit of a misnomer. While closed-loop scrubbers do remove some solids, the sludge ultimately ends up in a landfill, usually as hazardous waste (Kjølholt et al., 2012). Open-loop scrubbers typically do not have water treatment systems to remove solids before discharge, contrary to many schematics of scrubbers in the literature. The water flow rate of open-loop systems is often too high to allow for onboard treatment (European Sustainable Shipping Forum, 2017). Instead, whatever sludge could be captured from open-loop systems remains suspended in the washwater and is discharged overboard.

In response to the rapid uptake and use of scrubbers to comply with the IMO's 2020 global fuel sulfur limit, and concerns about the cumulative effects that more ships using scrubbers discharging acids, PAHs, heavy metals, and other pollutants could have on the marine environment, many countries are limiting or prohibiting scrubber discharges in their exclusive economic zones (EEZs), territorial seas, internal waters, canals, and/or ports, as shown in Table 1. We note that Canada has no such restrictions, despite significant and growing scrubber discharges, including 5.1 million tonnes in critical habitat for threatened and endangered Northern and Southern Resident killer whales off the coast of British Columbia as of 2017 (Georgeff, 2020).

Table 1. Locations where scrubber discharges are restricted or prohibited as of September 2020

Country	Details
Argentina	Prohibits open-loop (OL) discharge water in internal waters, territorial seas, and EEZs
Australia	Ships using scrubbers must notify Australian Maritime Safety Authority before port arrival
Bahrain	Prohibits OL discharges in territorial seas and EEZs unless they can be proven to comply with the 2015 IMO guidelines
Belgium	Discharges prohibited in ports, internal waters, and within 3 nautical miles (nm) of shore
Bermuda	Prohibits OL discharges in territorial seas; closed-loop (CL) discharges allowed with prior approval
Brazil	Discharges prohibited at Vale bulk terminals/ports; discharges discouraged within 24 nm of shore
China	Prohibits OL discharges in internal rivers and Domestic Emission Control Areas
Egypt	Discharges prohibited in territorial seas, ports, and the Suez Canal
Estonia	Discharges prohibited in ports and estuaries unless the ship owner can demonstrate that the discharge does not cause significant adverse effects
Finland	Discharges prohibited in the port of Porvoo
France	Prohibits OL discharges in some ports and rivers, including Bordeaux, Port Jérôme-sur-Seine, River Seine, and Le Havre
Germany	Discharges prohibited in internal waterways
Gibraltar	Prohibits OL discharges in waters of Gibraltar
Hong Kong	Use of scrubbers requires an exemption
Ireland	Discharges prohibited in ports of Dublin, Waterford, and Cork
Latvia	Discharges prohibited in territorial seas and ports
Lithuania	Discharges prohibited in ports
Malaysia	Prohibits OL discharges in territorial seas except for ships transiting the Malacca Strait that are not bound for a Malaysian port
Norway	Prohibits OL discharges in World Heritage Fjords sea areas of Geirangerfjord and Nærøyfjord
Oman	Discharges prohibited in territorial seas
Pakistan	Prohibits OL discharges in the ports of Karachi and Bin Qasim
Panama	Prohibits OL discharges in the Panama Canal
Portugal	Prohibits OL discharges in port
Qatar	Discharges prohibited in territorial seas
Saudi Arabia	Prohibits OL discharges in port
Singapore	Prohibits OL discharges in port
Spain	Prohibits OL discharges in the ports of Algeciras, Cartagena, and Huelva
Sweden	Discharges prohibited in the ports of Brofjorden, Gävle, Norrköping, Umeå, Sundsvall, Skellefteå, and Stockholm
United Arab Emirates	Prohibits OL discharges in the port of Fujairah
USA	California: Prohibits the use of scrubbers to comply with fuel sulfur limits within 24 nm Connecticut: Discharges prohibited in ports and waters of the state Hawaii: Discharges allowed, but special reporting required

Sources: Damgaard (2020) and Standard Club (2020)

Given this trend toward unilateral action by individual countries, the EU-28 and European Commission (EC) in 2019 proposed that IMO's Marine Environment Protection Committee (MEPC) undertake a new output to "evaluate and harmonize the development of rules and guidance on the discharge of liquid effluents from EGCS, including conditions and areas under which liquid effluents from EGCS can be discharged, and to regulate as appropriate access for ships equipped with such systems on that basis" (MEPC 74/14/1, para. 2). In their submission proposing a new output on harmonizing rules and guidance for EGCS discharges, the EU and EC explain that the only guidelines for EGCSs that currently apply are the 2015 guidelines, but that they do not have additional protections for sensitive areas. They also state that "it is questionable if the current criteria are fit for purpose in the current scenario, where a significant uptake of scrubbers or other technologies that discharge effluent into the marine ecosystem is occurring" (MEPC 74/14/1, para. 27).

MEPC 74 approved this new output on harmonizing rules and guidance for EGCS discharges, and tasked the Pollution Prevention and Response (PPR) subcommittee to work on the issue, with a target completion year of 2021. PPR 7 refined the title and scope of the output, which is expected to be approved at MEPC 75 (November 16–20, 2020) and will likely be sent back to PPR 8 to continue working on the topic. This provides an opportunity to develop guidance on when, where, or even if discharges should be allowed. It is likely that this work will focus on guidance for discharges in ports, harbors, estuaries, and busy shipping lanes, but Friends of the Earth International et al. (PPR 7/12/4) suggested that near shore areas, polar regions, and areas of cultural and ecological sensitivity and significance should also be considered.

A HISTORY OF IMO'S SCRUBBER GUIDELINES

The IMO first decided to regulate sulfur oxides (SO_x) from ships in the 1997 Protocol to the International Convention for the Prevention of Pollution from Ships (MARPOL), which included MARPOL Annex VI. Annex VI entered into force in May 2005 and contains regulations that limit SO_x and nitrogen oxides (NO_x) from ship exhaust. Sulfur oxides are primarily controlled by limiting the sulfur content of fuels, with one limit globally and another inside Sulfur Emission Control Areas (SECAs). Originally, scrubbers were to be allowed only within SECAs. However, a few months after Annex VI entered into force, IMO began revising it. In the revision, the IMO agreed that the maximum fuel sulfur content of marine fuels and the maximum NO_x emissions from marine engines would become more stringent over time. Additionally, ships would be allowed to use scrubbers globally, not just in SECAs under an "equivalence" provision added as Regulation 4. The revisions also introduced ECAs, which set stronger limits for not only SO_x, but also NO_x. Currently, there are four ECAs (Table 2). These revisions to MARPOL Annex VI were adopted in 2008 and entered into force in July 2010.

Despite scrubbers being allowed as an alternative SO_x compliance option under Regulation 4 of MARPOL Annex VI, port and coastal states are free to unilaterally limit or prohibit the use of scrubbers in their jurisdictions. Today, scrubber discharges are limited or prohibited in the territorial seas, internal waters, ports, or canals of at least 29 countries (Table 1). Canada currently has no restrictions on scrubbers.

Table 2. Current Emission Control Areas

Region	Applied for	Adopted	Enforced
Baltic Sea	1995 (SECA) 2016 (ECA)	1997 (SECA) 2017 (ECA)	2006: 1.5% max S 2010: 1% max S 2015: 0.1% max S 2021: Tier III NO_x
North Sea	2000 (SECA) 2016 (ECA)	2005 (SECA) 2017 (ECA)	2007: 1.5% max S 2010: 1% max S 2015: 0.1% max S 2021: Tier III NO_x
North America (United States & Canada, except the Arctic)	2009 (ECA)	2010 (ECA)	2012: 1% S max 2015: 0.1% S max 2016: Tier III NO_x
United States Caribbean Sea (Puerto Rico & U.S. Virgin Islands)	2010 (ECA)	2011 (ECA)	2014: 1% S max 2015: 0.1% S max 2016: Tier III NO_x

The IMO has established EGCS guidelines[1] for certain pollutants and other parameters (e.g., pH and temperature) for scrubber discharge water, but these guidelines are voluntarily applied by flag states, do not cover all pollutants (heavy metals are not explicitly included; turbidity is used as a proxy), and lack rigorous scientific justification. Endres et al. (2018) concluded that despite the existing IMO guidelines, "there is still the

1 IMO proposed revised 2020 guidelines for scrubbers at the 7th session of its Pollution Prevention and Response Sub-Committee (PPR 7); while they have not yet been adopted by the Marine Environment Protection Committee, we expect them to be approved at MEPC 75. Nevertheless, the discharge criteria established in the 2015 guidelines, as found in IMO Resolution MEPC.259(68), remains unchanged. The text of the 2015 guidelines are available here: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/MEPC.259%2868%29.pdf

risk for acidification, eutrophication, and accumulation of PAHs, PM [particulate matter], and heavy metals in the marine environment" (p. 139).

The first IMO scrubber guidelines can be found in Resolution MEPC.130(53), adopted in 2005. IMO subsequently published 2008, 2009, and 2015 guidelines in Resolutions MEPC.170(57), MEPC.184(59), and MEPC.259(68). Draft 2020 guidelines have been proposed in Annex 9 of document PPR 7/22/Add.1 and are expected to be approved by MEPC 75 in November 2020.

Regarding air emissions, all guidelines require that scrubbers result in SO_2/carbon dioxide (CO_2) ratios that are less than or equal to those that would result from burning compliant fuels. These limits are based on sulfur content and are summarized in Table 3. Note that only the 0.50% and 0.10% values are relevant after January 1, 2020. As such, the rest have been grayed. While all scrubbers tend to easily meet these SO_2 limits, researchers have found that when accounting for total sulfur emissions (gaseous + particle phase), scrubbers may emit more total sulfur than compliant fuel (Johnson et al., 2017). The guidelines set no limits on any air pollutant other than SO_2.

Table 3. Air emissions limits for ships with scrubbers

Fuel sulfur content (% m/m)	SO_2 (ppm)/CO_2 (% v/v)
4.50	195.0
3.50	151.7
1.50	65.0
1.00	43.3
0.50	21.7
0.10	4.3

MEPC.130(53): 2005 GUIDELINES—THE FIRST SCRUBBER GUIDELINES

In the original scrubber guidelines, found in Resolution MEPC.130(53) and adopted by MEPC 53 on July 22, 2005, scrubbers were expected to be used solely inside of SECAs, as allowed under the Protocol of 1997, which entered into force on May 19, 2005. Under the original guidelines, scrubber washwater was to be monitored for pH and oil content, but no numeric discharge criteria were proposed for either parameter. Instead, section 17 states the following:

> *17. Wash Water*
>
> *EGCS-SO_X unit's wash water systems should:*
>
>> *(a) eliminate, or reduce to a level at which they are not harmful, hydrocarbons, carbon residue, ash, vanadium, other heavy metals, and other substances contained within EGCS-SO_X unit's wash water that may have an adverse impact on ecosystems if discharged overboard,*
>>
>> *(b) ensure that the approach adopted, to control wash water quality and residual waste is not achieved in a way that causes pollution in other areas or environmental media,*
>>
>> *(c) also taking into account guidelines to be developed by the Organization.*

Regarding scrubber residues (sludge), section 18.1 makes it clear that they should be disposed of on land and not discharged overboard or incinerated on board:

> *18.1 Residues generated by the EGCS-SO_X unit should be land disposed. Such residues should not be discharged to the sea or incinerated on board.*

MEPC.170(57): 2008 GUIDELINES—WHERE THE FIRST AND ONLY DISCHARGE CRITERIA WERE ESTABLISHED

In 2008, there were only three ships with scrubbers, according to DNV GL (2020). In the 2008 guidelines, found in Resolution MEPC.170(57), which were adopted by MEPC 57 on April 4, 2008, the first discharge criteria were set, but only when the "EGC System is operated in a *[sic]* ports, harbours, or estuaries" (section 10.1.1). It includes criteria for pH, PAH, turbidity/suspended particulate matter, and nitrates. Although subsequent guidelines have expanded the discharge limits to apply beyond ports, harbors, and estuaries, the discharge limits first established in these 2008 guidelines have never been revised to be more stringent.

The 2008 guidelines were adopted at MEPC 57, but the work on setting discharge criteria had begun in 2006. MEPC 55, which was held October 9–13, 2006, established a correspondence group on Washwater Criteria for Exhaust Gas-SO_x Cleaning Systems. In establishing these discharge criteria, the correspondence group considered proposals from the United Kingdom (MEPC 55/4/5) as well as Finland and Norway (MEPC 55/4/7).

The UK document proposed that discharge criteria be established for pH and oil concentration (measured as PAH). They proposed that the pH of the discharge plume should not exceed 0.2 pH units below the background water conditions at a distance of 1 meter from the ship. They also proposed a 30 ppb (approximately equal to 30 µg/L) limit for PAHs, associated with a 50 tonnes per megawatt hour (t/MWh) flow rate. The same UK document shows that the 2000 EU Water Framework Directive sets drinking water standards of 0.01 ppb for total PAH. The 1992 Australian Water Quality Guidelines set a 3 ppb limit. In the 1992 Convention on the Protection of the Marine Environment of the Baltic Area, the Baltic Marine Environment Protection Commission, better known as HELCOM, set a 15 ppb limit for PAHs. The UK document provides the results of a 2004 study of discharges from an open-loop scrubber fitted to a European ferry, the *Pride of Kent*. In that study, the authors found that the maximum PAH concentration was 24 ppb, and that was in the residue settling tank. Typical PAH concentrations were 3–4 ppb compared with <0.6 ppb at the inlet, they said. It is perplexing why the UK would propose a limit of 30 ppb PAH at 50 t/MWh flow rate for ships with scrubbers, a level unlikely to be exceeded, given that typical concentrations were between 3 and 4 ppb. Indeed, as we will show in the results, we found that ships rarely exceed the PAH limits, which under the current guidelines allow discharges of approximately 50 µg/L (~50 ppb) at a 45 t/MWh flow rate.

The Norway and Finland document (MEPC 55/4/7) also proposed discharge criteria based on testing data from two ships, one ferry and one oil tanker, each outfitted with prototype open-loop scrubbers. The tests were conducted in 1991 and 1993. The minimum pH after the scrubber was recorded as 2.7. They assert that, due to dilution, even a pH of 0 would not result in a pH of less than 6.8, which is the most conservative

Predicted No Effect Concentration (PNEC[2]) they found in the literature, at a distance of at least 20 meters from the ship. The maximum PAH concentration in the scrubber washwater was 0.25 µg/L (~0.25 ppb), compared with the most conservative PNEC they could find in the literature, which was 3.3 µg/L. The Norway and Finland document suggests that, due to dilution effects, PAHs could be discharged at concentrations of approximately 6,200 µg/L while maneuvering or in transit, or more than 460 µg/L during quayside maneuvering and still not exceed the PNEC. Based on this, they recommend three tiers of criteria that port states could choose, with each level being 10 times more protective than the other. For pH, they suggested no limit. For PAH, they suggested a limit of 450, 45, or 5 µg/L (presumably rounded up from 4.5 µg/L), depending on the level of protection the port state would like to impose. They also proposed possible discharge criteria for heavy metals including nickel (Ni), vanadium (V), copper (Cu), lead (Pb), mercury (Hg), and cadmium (Cd) in units of µg/L, following the same tiered approach. However, individual heavy metal discharge criteria never made it into any scrubber guidelines because onboard monitoring is thought to be challenging. It should be understood that the modeling exercise presented in the Finland and Norway document, which showed no predicted adverse effects even at high pollution concentrations, is based on pollution discharges from one ship, whereas ports, harbors, estuaries, nearshore areas, and shipping lanes now experience scrubber discharge loads from multiple ships. Moreover, the number of ships with scrubbers is growing, as shown in Figure 1.

Ultimately, the correspondence group established by MEPC 55 did not propose specific discharge criteria limits. However, the group reported that most group members agreed that pH and oil concentration were two key performance parameters for scrubbers. The correspondence group suggested that a working group be established at MEPC 56 to finalize the discharge criteria.

At MEPC 56, which was held July 9–13, 2007, the Working Group on Air Pollution considered the report of the IMO Correspondence Group that MEPC 55 had established on Washwater Criteria for Exhaust Gas-SOx Cleaning Systems (their report is found in document MEPC 56/4/1) and developed a draft set of washwater discharge criteria for pH, oil (using PAHs as a proxy), heavy metals (using turbidity as a proxy), and nitrates. The report of the Working Group on Air Pollution (MEPC 56/WP.6) does not explain how it arrived at the discharge criteria for these parameters.

The criteria agreed to in the MEPC 56 Working Group on Air Pollution in the report are summarized in the annex to document BLG-WGAP 2/4. As stated in that document, MEPC 56 recommended a minimum outlet pH of 6.5 and a maximum difference between inlet and outlet of 2 pH units while the ship was at berth or at anchor in a port, harbor, or estuary. (In the eventual 2008 guidelines, this 2 pH difference would apply only to ships while maneuvering or in transit.) We note that because pH is a logarithmic scale, a difference of 2 pH units is equal to a 100-fold difference in acidity. They also suggested that, while underway in all areas, the pH should be maintained at a level that avoids acute effects on aquatic ecosystems, damage to antifouling systems, and accelerated corrosion of critical metal components. These considerations were lost in the eventual 2008 guidelines.

2 PNEC is the limit below which no adverse effects from exposure are measured.

For PAHs, MEPC 56 suggested a limit of 15 ppb at a discharge rate of 45 t/MWh. This would be weakened to 50 µg/L under the 2008 guidelines. For turbidity, they recommended a maximum of 25 formazin nephelometric units (FNU), which remained, although an alternative limit of 25 nephelometric turbidity units (NTU) was added under the 2008 guidelines. For nitrates, they suggested no nitrate limit for EGCS units designed to reduce oxides of nitrogen by less than "[10] per cent" (BLG-WGAP 2/4, annex 2, p. 2). Otherwise, they suggested that the discharge limit should be less than that associated with a "[10] per cent" removal of NO_x from the exhaust. No scrubbers are designed to remove NO_x, so no nitrate discharge limits for scrubbers would be needed had the first clause remained. This first clause would later be removed, and the second clause was weakened to allow 12% removal of NO_x or 60 mg/L of nitrates, whichever is greater, under the 2008 guidelines. The MEPC 56 Air Pollution Working Group advised MEPC not to adopt the draft 2008 guidelines yet and to instead send them to the second intersessional meeting of the Bulk Liquids and Gases Working Group on Air Pollution (BLG-WGAP 2) for further review and refinement.

BLG-WGAP 2 met from October 29, 2007, to November 2, 2007, in Berlin to work on the 2008 scrubber guidelines based on the draft washwater criteria developed by MEPC 56. BLG-WGAP 2 was instructed by MEPC 56 to finalize the draft revision to the 2005 guidelines found in MEPC.130(53), to finalize discharge criteria for EGCS from MEPC 56, and to include them in the draft amended 2008 guidelines. BLG-WGAP 2 did not finalize the draft washwater discharge criteria, so they were sent to BLG 12, which was held in February 2008, and they were also sent directly to MEPC 57, which was held in April 2008.

BLG 12 had for their consideration the draft discharge criteria from BLG-WGAP 2 in annex 6 to document BLG 12/6/Add.1. However, the discharge criteria BLG 12 ultimately recommended to MEPC 57 in document BLG 12/WP.6/Add.4 were weaker than those proposed by BLG-WGAP 2. The report of the BLG 12 Air Pollution Working Group (BLG 12/WP.6) contains no explanation or justification for this decision. The discharge criteria agreed to by BLG 12 were ultimately adopted, without revision, by MEPC 57 as the 2008 guidelines in Resolution MEPC.170(57) on April 4, 2008. Since then, the guidelines have been reviewed three times (2009, 2015, and 2020), and the discharge criteria have never been revised.

Below, for each parameter—pH, PAH, turbidity, and nitrates—we compare the recommendations of BLG-WGAP 2, as found in document MEPC 57/4/1, to the 2008 guidelines that MEPC 57 agreed to in Resolution MEPC.170(57). Table 4 details changes to the discharge criteria over time for these pollutants as well as heavy metals, compared with the number of ships with scrubbers installed during the year in which the revised guidelines were adopted. As the table shows, despite a review of the guidelines in 2009, 2015, and 2020, the discharge criteria that were initially established in the 2008 guidelines have never been revised and no numeric discharge criteria have ever been established for any heavy metal. Meanwhile, the number of ships with scrubbers has grown from three ships in 2008 to more than 4,300 ships in 2020.

Table 4. How IMO scrubber discharge criteria have changed over time, compared with the number of ships with scrubbers installed

Pollutant	MEPC.130(53): 2005 guidelines	MEPC 57/4/1: proposed discharge criteria from BLG-WGAP 2 for 2008 guidelines	MEPC.170(57): 2008 guidelines, as adopted by MEPC 57	MEPC.184(59): 2009 guidelines	MEPC.259(68): 2015 guidelines	PPR 7/22/ Add.1, Annex 9: Draft 2020 guidelines
pH	Eliminated or reduced "to a level at which they are not harmful."	pH ≥ 6.5 stationary; max Δ 2 pH units when moving	pH ≥ 6.5 stationary; max Δ 2 pH units when moving. OR pH ≥ 6.5 in the plume at 4 m while stationary	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*
PAH	Eliminated or reduced "to a level at which they are not harmful."	Max Δ 15 ppb PAH_{16} at 45 t/MWh	Max Δ 50 µg/L (~50 ppb) of PAH_{phe} at 45 t/MWh	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*
Turbidity	Eliminated or reduced "to a level at which they are not harmful."	Max Δ < 25 FNU or NTU; minimize suspended PM, including heavy metals and ash	Same as MEPC 57/4/1	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*
Nitrates	Eliminated or reduced "to a level at which they are not harmful."	Not > that associated with a [10%] removal of NO_x from the exhaust, or beyond [1] mg/L at 45 t/MWh, whichever is greater.	Not > that associated with a 12% removal of NO_x from the exhaust, or beyond 60 mg/L at 45 t/MWh, whichever is greater.	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*	*Unchanged from 2008 guidelines*
Heavy metals	Eliminated or reduced "to a level at which they are not harmful."	No limits	No limits	No limits	No limits	No limits
Ships with scrubbers	2	3	3	6	243	4,341 installed or on order through 2020

pH

BLG-WGAP 2 recommended that scrubber washwater have a pH of not less than 6.5 while at berth, but when maneuvering and in transit the limit would be a maximum difference of 2 pH units between inlet and outlet. MEPC 57 agreed but kept an alternative compliance option introduced by BLG 12 that would allow setting the scrubber's overboard pH discharge limit based on whatever pH achieved a minimum pH of 6.5 in the plume at a distance of 4 meters from the overboard discharge point. This introduces myriad confounding factors. The overboard discharge limit, in this case, would depend on the alkalinity of the inlet water, wind, waves, depth, sampling location, and other parameters. Moreover, setting the overboard pH discharge limit based on achieving a minimum pH of 6.5 at 4 meters from the overboard discharge point *ensures* that the pH will be less than 6.5 at the overboard discharge point and is therefore less protective. Given that the pH of seawater is typically around 8.0, and that the pH scale is logarithmic, even achieving a pH of 6.5 means that the overboard discharge is 32 times more acidic than seawater. Additionally, ships typically mix the scrubber outlet water with "reaction water," which is usually ambient seawater, before discharging it overboard, artificially raising the pH before it is monitored, while emitting the same total amount of acids overboard.

Note that the U.S. Environmental Protection Agency (EPA) under its 2013 Vessel General Permit (VGP) requires a pH of no less than 6.0 at the overboard discharge point, or a maximum difference of 2 pH units during maneuvering and transit. However, the EPA does not allow the second provision (i.e., a pH of no less than 6.5 at 4 meters) because the minimum pH of 6.0 at the point of discharge is weaker than the IMO's minimum pH of 6.5 at overboard discharge and likely results in a pH greater than 6.5 at 4 meters. The EPA (2013) explains in its VGP fact sheet that allowing a minimum pH of 6.0 while disallowing the 4-meter provision is simpler, while essentially consistent with the IMO guidelines. However, in October 2020, the EPA issued a proposed rule that would harmonize its pH requirement with the IMO's 2015 guidelines (U.S. EPA, 2020). The EPA is accepting comments through November 2020.

PAH

BLG-WGAP 2 agreed that PAH was an appropriate indicator of oil content for scrubber washwater. They suggested that the U.S. EPA's 16 criteria PAHs (PAH_{16}) should be measured and that washwater criteria for PAH be further reviewed at BLG 12. At BLG 12, PAH_{16} was replaced with phenanthrene equivalence (PAH_{phe}) and the discharge limit was weakened. The original discharge limit was 15 ppb (approximately equal to 15 µg/L) of PAH_{16}; in other words, the sum total of EPA's 16 criteria PAHs. This was replaced with 50 µg/L of PAH_{phe}. Both limits were associated with a normalized washwater discharge rate of 45 t/MWh. Both the BLG-WGAP 2 recommendations and the 2008 guidelines explain that the PAH concentration should be measured downstream of any water treatment equipment, but upstream of any dilution or reactant dosing prior to discharge.

Turbidity

Both MEPC 57/4/1 and MEPC.170(57) set the limit at 25 NTU or FNU, although we found no justification for this limit. Additionally, "the discharge water treatment system should be designed to minimize suspended particulate matter, including heavy metals and ash," although there are no specific numeric limits associated with this. Also, open-loop systems do not typically have discharge water treatment systems.

Nitrates

For nitrates, BLG-WGAP 2 had draft limits in bracketed text associated with no more than a 10% removal of NO_x or 1 mg/L, whichever is greater. The bracketed text means the group could not agree on an exact limit and the "whichever is greater" language already sets a weaker standard than had it been phrased as "whichever is lower." During BLG-WGAP 2, the European Association of Internal Combustion Engine Manufacturers (EUROMOT) wanted to weaken the provision further by increasing the limit to that associated with a 20% removal of NO_x. Ultimately, BLG 12 agreed to somewhat weaken the draft limit from 10% to 12%, but also to dramatically increase the allowable nitrate concentration from 1 mg/L to 60 mg/L. Scrubber discharges can comply with the guidelines for nitrate concentrations under either limit. In practice, the concentration limit is easier to demonstrate compliance with, rather than trying to estimate what nitrate concentration would be associated with a 12% removal of NO_x. Additionally, because scrubbers are not designed to remove NO_x and, as we will show in the results, are expected to have no impact on NO_x emission factors, the relevant nitrate limit is 60 mg/L, because it is the greater of the two. The 2008 guidelines did not explain whether the nitrate limit was based on the discharge concentration or the difference between inlet and outlet concentrations. It was clarified in the draft 2020 guidelines that the limit is based on the latter. This clarification itself is a weakening of the nitrate limit, because seawater often contains nitrates. However, it is understandable that the guidelines would be interested in preventing additional nitrates from the scrubber system. We should note that washwater discharges contain both nitrates and nitrites; the IMO guidelines cover only nitrates. The United States, in its 2013 VGP, requires the sum of nitrates and nitrites to be less than 60 mg/L.

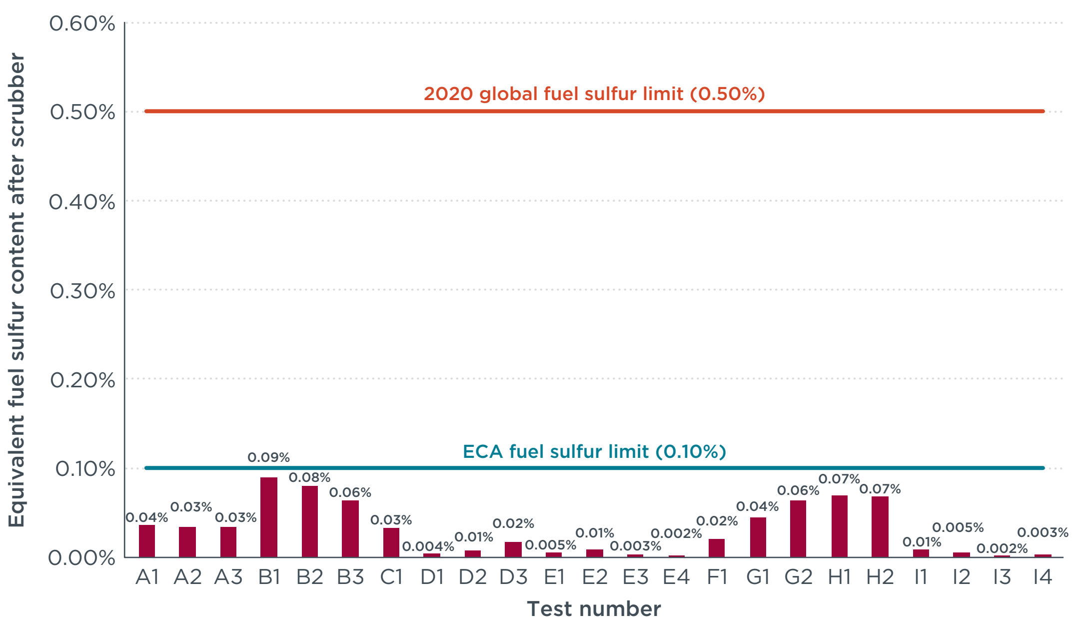
RESULTS

This section summarizes the air and water emissions associated with scrubbers based on a review of the available literature and our own calculations.

AIR EMISSIONS

We found eight studies representing 23 samples that contained information on air emissions from scrubbers (Fridell & Salo, 2016; Interlake Steamship Company, 2018; Johnson et al., 2017; Johnson, Miller, & Yang, 2018; Lehtoranta et al., 2019; Timonen et al., 2017; Wärtsilä, 2010; Winnes, Fridell, & Moldanová, 2020). We compared the emissions from ships with scrubbers to expected values for other marine fuels, based on the emission factors in the *Fourth IMO Greenhouse Gas Study* (Faber et al., 2020). A detailed spreadsheet containing information about ship type, engine, scrubber type, and emission factors is provided in the supplemental material.

We calculated the equivalent fuel sulfur content of ships with scrubbers based on the SO_2 emissions after the scrubber and the engine's specific fuel oil consumption (SFOC, measured in grams of fuel per kilowatt hour, g/kWh).[3] As shown in Figure 2, we found that all ships with scrubbers emitted SO_2 in amounts low enough to achieve equivalent fuel sulfur contents that were lower than both the 2020 global fuel sulfur limit of 0.50% and the ECA fuel sulfur limit of 0.10%. The original fuel sulfur content is presented in the table directly below the chart in the figure. While ships with scrubbers achieve lower SO_2 emissions than if they had used lower-sulfur fuels, other air pollutants are higher for ships with scrubbers than using ECA-compliant fuels, such as marine gas oil (MGO), as we explain next.



A	B	C	D	E	F	G	H	I
1.89%	2.50%	2.30%	2.77%	0.65%	1.90%	1.24%	1.35%	0.65%

Figure 2. Equivalent fuel sulfur content after the scrubber, with original fuel sulfur contents in the table.

3 Equivalent fuel sulfur content (% m/m) = gSO_2/kWh ÷ (SFOC × 0.97753 × 2).

Table 5 shows the relative emissions in the exhaust for a ship using 2.60% sulfur heavy fuel oil (HFO) with a scrubber compared with other marine fuels, including 2.60% sulfur HFO without a scrubber, 0.50% sulfur very low sulfur fuel oil (VLSFO), 0.10% sulfur marine gas oil (MGO), and 0.07% sulfur MGO (global average fuel sulfur content as of 2019).

Table 5. Relative emissions change after the scrubber when using HFO (2.6% S) compared with other fuels

Comparison: 2.6% S HFO + scrubber versus...	SO_2	CO_2	PM_{10}	$PM_{2.5}$	NO_x	CO	BC (SSD)	BC (MSD)
HFO (2.6% S)	-98%	+2%	-79%	-79%	0%	-11%	-9%	-11%
VLSFO (0.50% S)	-90%	+4%	-59%	-59%	0%	-11%	unknown	unknown
MGO (0.10% S)	-52%	+4%	+61%	+61%	0%	-11%	+353%	+81%
MGO (0.07% S)	-31%	+4%	+69%	+69%	0%	-11%	+353%	+81%

We found that scrubbers can substantially reduce SO_x emissions, with average SO_2 emissions 31% lower than 0.07% sulfur MGO. Based on SO_2 emissions and fuel consumption, we calculated the equivalent fuel sulfur content, as shown in Figure 2. One must remember that scrubber SO_2 performance depends on a number of factors. The performance will vary based on the sulfur content of the fuel, engine power, engine load, scrubber water flow rate, and the alkalinity of the inlet or recirculating water. While all of the scrubbers tested meet the 0.10% ECA sulfur limit, it is possible that scrubber parameters may be adjusted to only just meet the relevant sulfur limits. For example, if a ship is operating outside of an ECA, the scrubber flow rate may be adjusted down to allow SO_2 emissions that would correspond to 0.50% sulfur fuel. In that case, the SO_2 emissions reductions from scrubbers compared with VLSFO and MGO would be overestimated when the ship is operating outside of ECAs. If scrubber operations are modified to allow higher sulfur emissions outside of ECAs, direct PM emissions would also increase. Therefore, although we found that using 2.6% sulfur HFO with a scrubber can reduce PM emissions compared with using 0.50% sulfur VLSFO, this reduction would be overestimated if scrubber parameters are adjusted to allow higher emissions outside of ECAs. Likewise, our finding that PM emissions for ships using 2.6% sulfur HFO with a scrubber were nearly 70% higher than MGO, on average, would be an underestimate, meaning that PM emissions from ships using HFO with scrubbers could be even higher on the high seas.

For climate pollutants, including CO_2 and black carbon (BC), using HFO with scrubbers results in higher emissions than MGO. Average CO_2 emissions were 4% higher using HFO with a scrubber compared with MGO. BC emissions using HFO with a scrubber were expected to be 81% higher than using 0.07% sulfur MGO in a medium-speed diesel (MSD) engine and more than 4.5 times higher than using MGO in a slow-speed diesel (SSD) engine. This is because both MSD and SSD engines emit substantially more BC emissions when using residual fuels such as HFO compared with distillate fuels like MGO (Comer, Olmer, Mao, Roy, & Rutherford, 2017; Faber et al., 2020; Olmer, Comer, Roy, Mao, & Rutherford, 2017). Therefore, even though the scrubber removes some BC from the exhaust (roughly 10%), ships using HFO with scrubbers still emit more BC than those using MGO.

Emissions of NO_x were sometimes lower and sometimes higher after the scrubber; however, based on the studies we reviewed, we found the average effect to be 0%. We do not expect scrubbers to have a significant direct impact on NO_x emissions because

NO_x formation is more sensitive to other parameters, including combustion temperature. We also found that scrubbers seem to somewhat reduce carbon monoxide (CO) emissions (-11% on average) across fuels. The mechanism by which scrubbers reduce CO emissions deserves further investigation. Based on these findings, Table 6 provides recommended emission factors for ships using HFO in combination with scrubbers.

Table 6. Recommended emission factors (g/kWh) for ships using HFO + scrubbers

Engine type	Engine age	SFOC (g/kWh)	Sulfur content	Carbon factor, Cf (gCO_2/g fuel)	Engine RPM	SO_2	CO_2	PM_{10}	$PM_{2.5}$	NO_x	CO	BC
SSD	<1984	209	2.60%	3.114	<130	0.19	650	0.30	0.28	18.2	0.48	0.04
SSD	1984-1999	188	2.60%	3.114	<130	0.17	586	0.30	0.27	18.2	0.48	0.03
SSD	2000-2010	178	2.60%	3.114	<130	0.16	554	0.30	0.27	17.1	0.48	0.03
SSD	2011-2015	178	2.60%	3.114	<130	0.16	554	0.30	0.27	14.5	0.48	0.03
SSD	2016+ outside ECA	178	2.60%	3.114	<130	0.16	554	0.30	0.27	14.5	0.48	0.03
SSD	2016+ in ECA	178	2.60%	3.114	<130	0.16	554	0.30	0.27	3.4	0.48	0.03
MSD	<1984	219	2.60%	3.114	720	0.20	681	0.30	0.28	14.1	0.48	0.09
MSD	1984-1999	198	2.60%	3.114	720	0.18	618	0.30	0.28	14.1	0.48	0.08
MSD	2000-2010	188	2.60%	3.114	720	0.17	586	0.30	0.27	12.1	0.48	0.08
MSD	2011-2015	188	2.60%	3.114	720	0.17	586	0.30	0.27	9.7	0.48	0.08
MSD	2016+ outside ECA	188	2.60%	3.114	720	0.17	586	0.30	0.27	9.7	0.48	0.08
MSD	2016+ in ECA	188	2.60%	3.114	720	0.17	586	0.30	0.27	2.4	0.48	0.08

In Table 7, we have estimated the expected life-cycle CO_2 emissions from ships using HFO with scrubbers compared with other fuels. We have taken into account the relative energy density and carbon factor (Cf) of each fuel based on the *Fourth IMO Greenhouse Gas Study* (Faber et al., 2020). We have also shown how SFOC changes based on fuel type and whether or not a scrubber is used. We assumed an SSD engine built in the year 2001 or newer. These SFOCs are consistent with the *Fourth IMO Greenhouse Gas Study*. We have added a 2% fuel consumption increase for HFO with scrubbers compared with HFO without scrubbers, consistent with our findings in Table 5, which show that using HFO with a scrubber emits 2% more CO_2 emissions than HFO without a scrubber. For VLSFO, we assume that it is an 80/20 blend of MGO and HFO to achieve a maximum 0.50% sulfur content.

Combustion emissions in grams of CO_2 per kilowatt-hour out (gCO_2/kWh out) are calculated by multiplying Cf (gCO_2/g fuel) by SFOC (g fuel/kWh out).

Upstream emissions (gCO_2/kWh out) are calculated as follows:

$$U_{out} = U_{in} \times \frac{EC}{1000} \times SFOC$$

U_{out} = upstream emissions (gCO_2/kWh out)

U_{in} = upstream emissions (gCO_2/MJ in) from GREET (Argonne National Laboratory, 2019), which is 13.5 for MGO and 10.7 for HFO; VLSFO is assumed to be 12.9, reflecting an 80/20 mix of MGO and HFO.

EC = energy content (kJ in/g fuel) as found in Table 7; dividing by 1,000 converts to units of MJ in/g fuel

SFOC = specific fuel oil consumption (g fuel/kWh out), which is listed by fuel in Table 7

As shown in Table 7, the expected combustion emissions for ships with HFO and scrubbers are higher than using MGO, while the upstream emissions are lower. Adding the two together, we find that the total well-to-wake (WtWa) emissions for a ship using HFO with a scrubber are expected to be 1.1% higher than using MGO.

Table 7. Life-cycle CO_2 emissions for ships using HFO + scrubbers relative to other fuels

				(gCO_2/kWh out)			
Fuel	**Energy content (kJ/g fuel)**	**Cf (gCO_2/g fuel)**	**SFOC (g fuel/kWh out)**	**Combustion**	**Upstream**	**Well-to-wake (WtWa)**	**WtWa relative to MGO**
MGO	42.7	3.206	165	529	95	624	0.0%
VLSFO	42.2	3.188	167	532	91	624	-0.1%
HFO	40.2	3.114	175	545	75	620	-0.6%
HFO + scrubber	40.2	3.114	178	554	77	631	+1.1%

WATER POLLUTANTS

We reviewed 17 studies and found that only 10 had enough information to assess whether scrubber discharges were complying with IMO guidelines. We evaluated each study based on whether it included relevant information on the ship, fuel sulfur content, scrubber type, engines, engine operating parameters, discharge water flow rate, and transparency of results, as shown in Table 8.

Many industry-funded studies such as Faber et al. (2019) and Carnival (2019) lacked the necessary information to determine the total mass of pollution discharges and to assess whether they satisfied IMO guidelines. For example, in Faber et al. (2019), 253 samples were analyzed, but only generalized information on ship types and engine loads at berth were provided. No flow rate was reported, which makes it impossible to determine if the discharges comply with the IMO guidelines. Nevertheless, Faber et al. (2019) improperly compared unadjusted per-liter concentrations of PAHs and other pollutants to the discharge criteria in the 2015 IMO guidelines; this was improper because they did not normalize the pollutant concentrations to a specific washwater flow rate. The IMO guidelines limit PAH concentrations to 50 µg/L at a normalized washwater flow rate of 45 t/MWh. Faber et al. (2019) explained that the PAH concentrations in their study “were not normalized” (p. 38). They used this to argue that the samples that had PAH concentrations greater than 50 µg/L may still comply with the guidelines, when exactly the opposite could be true. Without normalizing the pollutant concentrations to a specific washwater flow rate, no conclusions can be drawn regarding compliance with, or exceedance of, IMO guidelines.

We omitted three other studies that were at least partially funded by industry. One from Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT, 2018), as well as Wärtsilä (2010) and Koski, Stedmon, and Trapp (2017). While the MLIT (2018) study included information for many of the evaluation criteria, we could not fully understand the experimental set-up and therefore excluded it. From what we can understand, MLIT (2018) evaluated the characteristics of scrubber discharge water generated in the lab using a 257 kW, medium-speed laboratory engine and a hybrid scrubber. While MLIT (2018) provided measured values for certain discharge criteria, it was not clear if they related to open-loop or closed-loop operations, or what engine power and flow rate were associated with those values. Wärtsilä (2010) did not report measured values for any discharge criteria. Koski et al. (2017) did not provide information on the associated flow rate, making it impossible to calculate the total mass of pollutants discharged.

Government-funded studies typically contained more details, although some government-funded studies did not include enough information, including U.S. EPA (2011), which did not contain information on fuel type, sulfur content, or flow rate. Additionally, Ytreberg et al. (2019), which was funded by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, focused on how microplankton respond to scrubber discharge water exposures, rather than evaluating scrubber performance against IMO's discharge criteria and tests were done using discharges generated by a small laboratory engine rather than from a ship, hence ship identification information is not applicable. With these exceptions, government-funded studies were the most useful for this analysis. In some cases, such as Teuchies, Cox, Van Itterbeeck, Meyseman and Blust (2020), which was funded by the independent municipal Antwerp Port Authority, the study included detailed supplemental material containing raw data that was made publicly available. Except for Teuchies et al. (2020), the downside is that the government-funded studies often were limited in scope. Only a handful were able to measure more than one ship, and almost all measured a ship in European waters.

Table 8. Evaluation of the quality of sources containing information on scrubber discharges

Source	Includes ship ID information (e.g., IMO number)?*	Includes fuel type and sulfur content?	Includes scrubber type?	Includes engine power?	Includes flow rate?	Includes raw data?	Grade (% based on a max score of 12)	Enough information to be used in this study?	Funding source
Hansen (2012)	2	2	2	2	2	2	100%	Y	Government
Kjølholt et al. (2012)	2	2	2	2	2	2	100%	Y	Government
Ushakov, Senersen, Einang, & Ask (2019)	2	2	2	2	2	2	100%	Y	Government
Zhu et al. (2016)	2	2	2	2	2	2	100%	Y	Government
Ytreberg et al. (2019)	n/a	2	2	2	2	2	100%	N	Government
Magnusson, Thor, & Grandberg (2018)	2	2	2	0	2	2	83%	Y	Government/ Industry
Teuchies et al. (2020)	0	2	2	2	2	2	83%	Y	Government
Winnes et al. (2018)	2	2	2	2	0	2	83%	Y	Government
Buhaug, Fløgstad, & Bakke (2006)	2	1	2	2	0	2	75%	Y	Government/ Industry
Germany (2018)	0	2	2	0	2	2	67%	Y	Government
Hufnagl, Liebezeit, & Behrends (2005)	2	1	2	1	0	2	67%	Y	Industry
Koski, Stedmon, & Trapp (2017)	2	2	2	0	0	2	67%	N	Government/ Industry
MLIT (2018)	0	2	2	2	1	1	67%	N	Government/ Industry
US EPA (2011)	2	0	2	2	1	1	67%	N	Government
Wärstilä (2010)	2	2	2	2	0	0	67%	N	Industry
Faber et al. (2019)	0	0	2	0	0	1	25%	N	Industry
Carnival (2019)	0	0	1	0	0	1	17%	N	Industry

*Grading scale for all criteria: 2 = all relevant data provided; 1 = some relevant data provided; 0 = no relevant data provided.

We identified 10 studies containing a total of 112 discharge samples that were of high enough quality to compare scrubber discharges to the discharge criteria in the IMO guidelines. In this section, we compare reported values from the literature against the discharge criteria for pH, PAH, turbidity, and nitrates contained in the draft 2020 guidelines, which can be found in document PPR 7/22/Add.1, annex 9. These are the same as the limits first established in the 2008 guidelines, which are found in Resolution MEPC.170(57).

pH

Ten studies representing 63 samples contained usable information on pH. The pH was measured at the overboard discharge point for all but one sample (test number 111). Twenty-seven samples were from closed-loop scrubbers, and 36 were from open-loop or hybrid scrubbers operating in open-loop mode. The pH was higher (less acidic) for closed-loop systems because the pH can be more directly controlled using alkaline materials, such as caustic soda, before discharging (Figure 3). The median pH for closed-loop systems was 7.59, while it was 5.63 for open-loop systems.

Of the 27 samples from scrubbers operating in closed-loop mode, all but seven had a pH ≥ 6.5, which would comply with the IMO guidelines for when the ship is stationary. All but four samples had a pH ≥ 6.0, which would comply with the EPA's 2013 VGP. It was not always clear in the literature if the ships were stationary, maneuvering, or in transit during the sampling. Nevertheless, all but one of the closed-loop samples also had a delta pH of less than 2, which would comply with both the IMO guidelines and the EPA 2013 VGP for ships that are maneuvering or in transit.

The pH was lower (more acidic) for open-loop systems, because the buffering solution is seawater, which has variable alkalinity. The pH also depends on the amount of reaction water, which is usually ambient seawater, mixed in before monitoring. As a result, only six out of 36 samples from open-loop scrubbers had a pH of ≥ 6.5, while 14 had a pH ≥ 6.0. Only 13 of 36 samples had a delta pH of less than 2, meaning that, had the ship been moving, 23 of 36 samples would have failed to comply with the IMO guidelines. Only one measurement in one study reported pH from a sample taken 4 meters away from the overboard discharge point (Ushakov et al., 2020); that was reported to have a pH of 6.52, which is high enough to comply with both the IMO guidelines and the EPA VGP.

Overall, closed-looped scrubbers performed the best in terms of pH, with 74% of samples having a pH ≥ 6.5 and 85% ≥ 6.0. Additionally, 96% of closed-loop samples had a delta pH < 2. Open-loop scrubbers, on the other hand, performed poorly, with only 17% of samples having a pH ≥ 6.5 and 39% having a pH of ≥ 6.0. Only 36% of open-loop samples had a delta pH less than 2. This is despite the practice of diluting the discharge with additional seawater before monitoring. Blending scrubber discharge water with ambient seawater prior to dumping it into the sea does not change how much acid is added to the surrounding waters; it merely raises the pH before it is monitored for comparison with the guidelines. Port State control officers may need to consider how to ensure that ships are complying with the delta 2 pH limit during maneuvering and transit of waters under their jurisdiction.

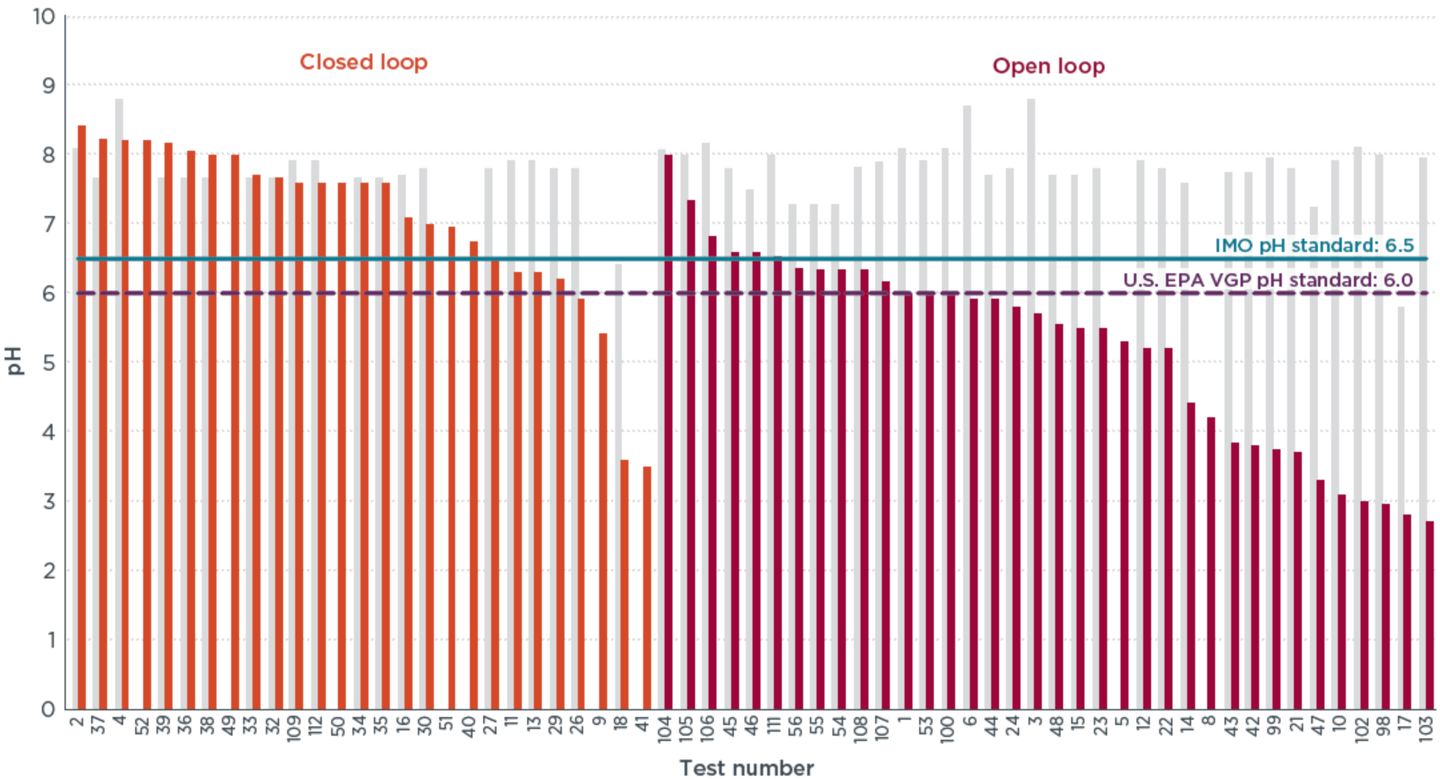


Figure 3. pH in scrubber discharge water. Gray bars show pH values before entering the scrubber system; orange and red bars show pH values after scrubbing process for closed- and open-loop scrubbers, respectively. Blue line indicates a pH of 6.5, consistent with IMO guidelines, and the purple dashed line is equal to a pH of 6.0, consistent with EPA 2013 VGP.

PAHs

Four studies representing 60 samples contained usable information on PAHs. Ten samples were from closed-loop scrubbers, and 50 were from open-loop scrubbers or hybrid scrubbers operating in open-loop mode (Germany, 2018; Kjølholt et al., 2012; Teuchies et al., 2020; Ushakov et al., 2020). Nearly all samples were below the PAH_{phe} limit. At 50 µg/L and 45 t/MWh, the maximum allowable discharge under the IMO guidelines is equivalent to 2,250,000 µg/MWh. As shown in Figure 4, 93% of samples complied with the IMO guidelines (note the log scale). Open-loop scrubbers emitted greater amounts of PAH_{phe} compared with closed-loop systems, oftentimes an order of magnitude higher. The median PAH_{phe} value for closed-loop systems was 6,630 µg/MWh, while it was 118,760 µg/MWh for open-loop systems.

Only four samples exceeded the discharge criteria for PAH_{phe}, and they were from open-loop scrubber measurements taken on board ships by Germany's Federal Maritime and Hydrographic Agency (Germany, 2018). The report, which tested washwater using onboard monitoring systems and additional in-situ measurements on board five ships, noted discrepancies between the two methods. It found that the onboard monitoring data showed lower PAH_{phe} values than the in-situ data. Worryingly, it also found that the onboard monitoring system seemed to be malfunctioning for two of the five ships, where PAH outlet concentrations were lower than inlet concentrations. This is highly unlikely, given that seawater has very low ambient concentrations of PAHs, so this suggested to the researchers that it was a calibration problem. While the onboard monitoring never found exceedances of the PAH_{phe} limits, the in-situ measurements showed that PAH_{phe} concentrations were greater than 50 µg/L in seven out of nine tests (two tests for each of four ships, plus one test for the fifth), but this was without normalizing the results to 45 t/MWh, which is what the guidelines are based on. We normalized them and found that four test points were above the discharge criteria, as shown in Figure 4.

The remaining studies that recorded open-loop discharges (Kjølholt et al., 2012; Teuchies et al., 2020; Ushakov et al., 2020) found PAH_{phe} emissions ranging from 7,000 to 1,600,000 µg/MWh, with an average of 900,000 µg/MWh. The large range indicates that open-loop PAH_{phe} discharges are inconsistent.

The two studies that reported closed-loop scrubber PAH_{phe} data (Germany, 2018; Teuchies et al., 2020) recorded PAH_{phe} discharges from the bleed-off water to be below the IMO guideline limits, within the range of 1,800 to 24,000 µg/MWh. Germany (2018) tested one ship with a closed-loop scrubber and, like the open-loop scrubbers they evaluated, noted significant discrepancies between the ship's onboard monitoring and the in-situ measurements for the closed-loop PAH_{phe} data. The in-situ PAH_{phe} measurements were as much as 33 times higher than those reported by the onboard monitoring system. Teuchies et al. (2020) compared their closed-loop PAH_{phe} measurements with the water quality standards of the European Water Framework Directive and noted that "the concentrations of most PAHs and all metals in closed loop bleed-off largely exceeded their WQS [water quality standards] and are expected to be acutely toxic for most aquatic organisms" (Teuchies et al., 2020, p. 7).

As previously mentioned, the current IMO guidelines are based on PAH_{phe}. Phenanthrene, which is a molecule of three fused benzene rings and is classified as a low molecular weight PAH of 178 g/mol, is one of 16 PAHs that is customarily analyzed. Out of the 16 PAHs, the molecular weights range from 128 g/mol for 2-ring naphthalene, to 276 g/mol for 6-ring Benzo[g,h,i]perylene. The tendency to bioaccumulate and to resist biodegradation generally increases with increasing molecular weight (Adeniji, Okoh, & Okoh, 2018). Selecting phenanthrene as the surrogate for all PAHs in discharge water has unclear origins. According to the U.S. EPA, the IMO's basis for selecting PAH_{phe} seems to be based on the fact that phenanthrene was found to be the most abundant PAH in the analysis of washwater during trials on the vessel *Pride of Kent,* which is reviewed in this report as Hufnagl et al. (2005). Recall that the United Kingdom used the *Pride of Kent* data in the submission to MEPC 55 that suggested a 30 ppb (~30 µg/L) limit for PAHs.

The U.S. EPA seems to find the IMO guidelines inadequate, given that monitoring 16 criteria PAHs is required in the 2013 EPA VGP. Bosch et al. (2009) critiqued the idea of "phenanthrene equivalents" as a proxy for measuring hydrocarbon emissions (i.e., oil), stating that the concept needs to be explained or replaced, due to the unknown amounts of other PAHs being emitted. Additionally, PAHs, phenanthrene and otherwise, are difficult to analyze on board. In some studies, discharge water samples were taken from the site and chemically analyzed in a lab. The onboard measurements depend on the measurement of the phenanthrene fluorescent intensity, and the results of that are dependent on the solubility of PAH_{phe} and proper calibration of the instrument (Tomioka & Hashima, 2019). Germany (2018) suggested higher calibration and maintenance frequency of the systems for onboard measurements after seeing the large discrepancies in detail between onboard and laboratory analyses.

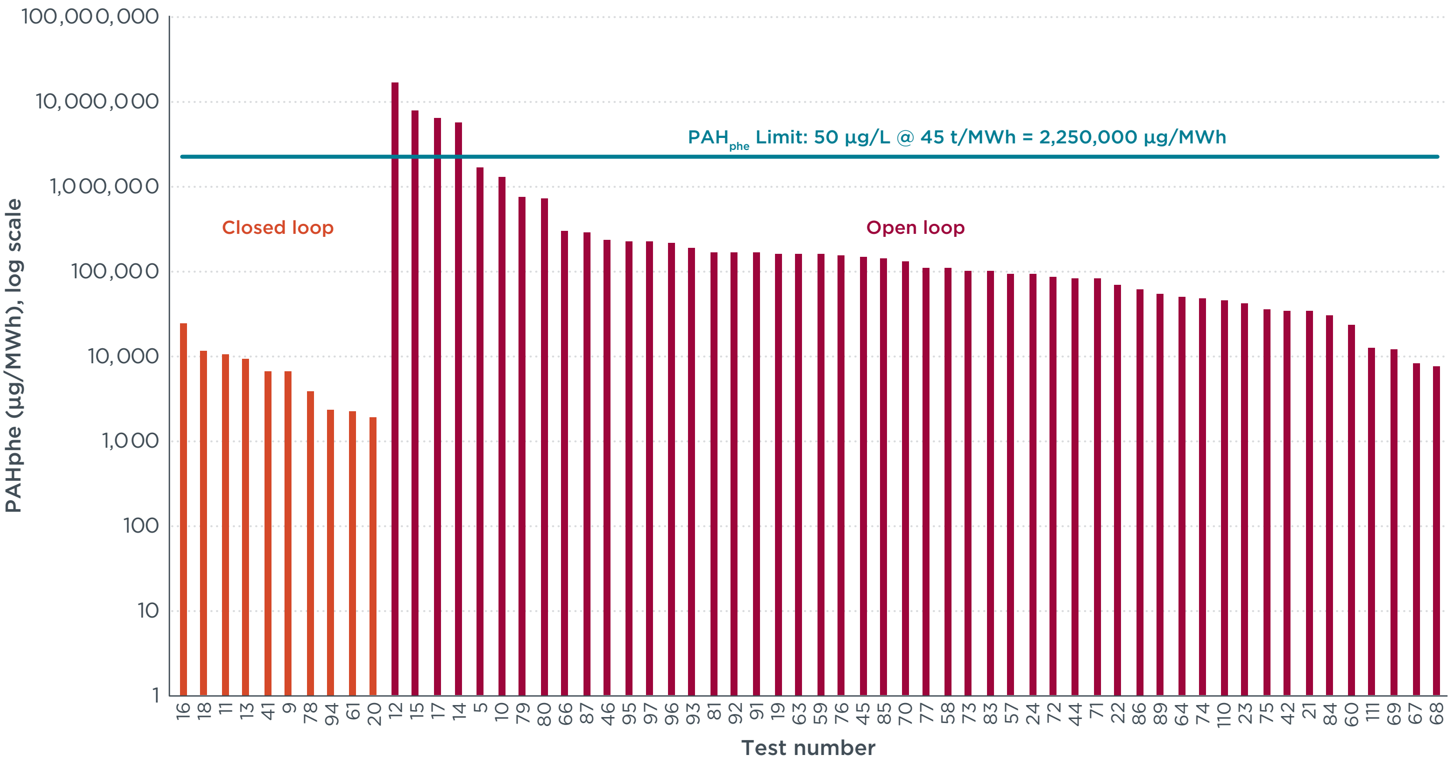


Figure 4. PAH$_{phe}$ in scrubber discharge water.

Turbidity

Six studies representing 17 samples contained usable information on the turbidity of scrubber discharge water. Eight samples were from closed-loop scrubbers, and nine from open-loop or hybrid scrubbers operating in open-loop mode. The median turbidity for closed-loop systems was 9.9 NTU and it was 1.1 NTU for open-loop systems.

Closed-loop discharges had higher turbidity than open-loop discharges. It may be that there is higher turbidity in the closed-loop bleed-off water because it is more highly concentrated than open-loop discharges. It could also be that because water is recirculated, it becomes more turbid over time, despite water treatment designed to remove suspended solids as sludge.

The turbidity measurement units (FNU and NTU) both measure turbidity based on light scattering, although FNU uses infrared light and NTU uses white light. Two studies, Hansen (2012) and Ushakov et al. (2020), measured turbidity using FNU (see test numbers 100 for Hansen and 110 and 111 for Ushakov et al.). The one sample that measured above the IMO guideline's discharge criteria of 25 came from Germany (2018), which found an increase of 26.6 NTU from inlet water to outlet water for a closed-loop scrubber. Magnusson et al. (2018) found that the water treatment system used to collect residues from the closed-loop system they tested reduced turbidity in the discharge 96%, but even then the overboard discharge was at least 7.3 NTU higher than the surrounding seawater. Because no zeros were recorded, every discharge increased turbidity compared with the ambient seawater.

The IMO guidelines state that "the discharge water treatment system should be designed to minimize suspended particulate matter, including heavy metals and ash"

(PPR 7/22/Add.1, annex 9, p. 21). In practice, while closed-loop scrubbers intentionally separate out suspended particulate matter and store it onboard as sludge for on-land disposal, open-loop systems typically do not. A survey of scrubber manufacturers showed that open-loop systems typically do not collect sludge, implying that suspended particulate matter, including heavy metals and ash, are discharged overboard and not actually passed through a water treatment system (European Sustainable Shipping Forum, 2017). If solids were separated out, turbidity would be reduced, and heavy metals could be reduced as well because they can be attached to suspended solids. However, because the discharge water has a lower pH, metals can more easily dissolve into the water, rather than being held in the sediments. This was seen in a study by Wärtsilä (2010), which found high concentration of metals even though turbidity was well below the IMO discharge criteria. The U.S. EPA (2011) noted that there is no correlation between turbidity and particle concentration. Ushakov et al. (2020) questioned the scientific significance of measuring turbidity. They noted that the measured values depend on the scattering of light and the light source used, which can be influenced by seawater organics. Smaller particles in the discharge water would have low influence on the turbidity and could be missed, even though they may be contributing to pollution. Lastly, bubbles were a common source of interference in several studies, including Zhu et al. (2016), U.S. EPA (2011), and Wärtsilä (2010).

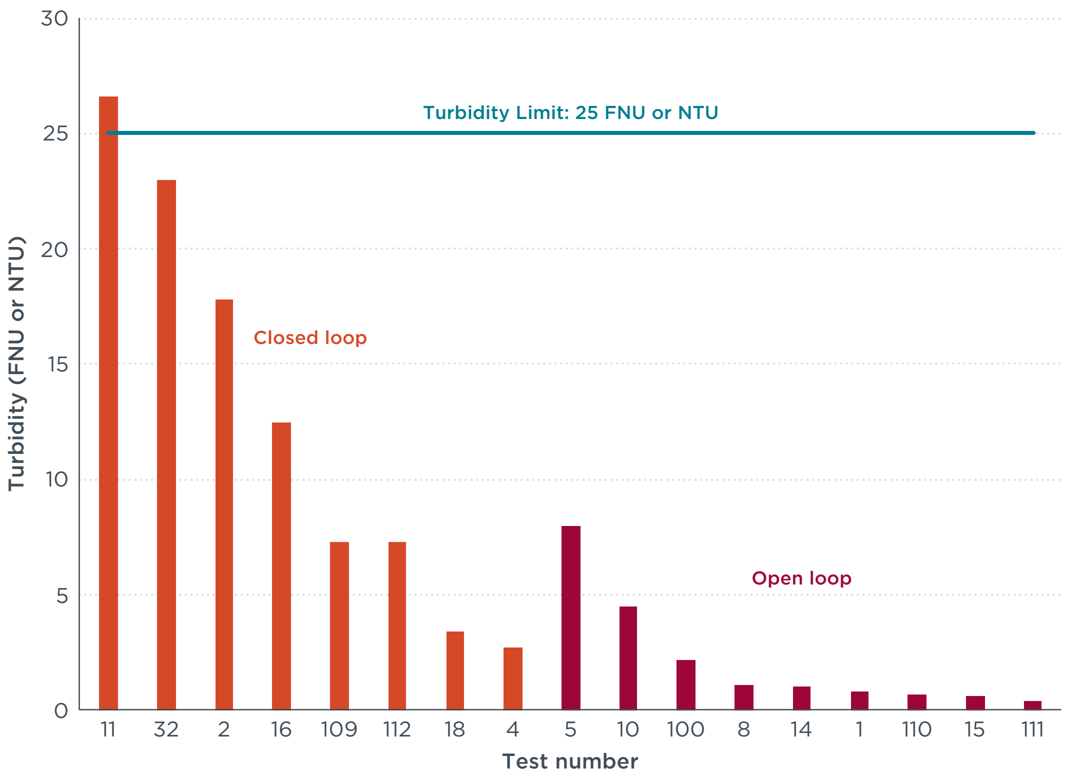


Figure 5. Turbidity in scrubber discharge water.

Nitrates

Four studies representing seven samples reported nitrates (Germany, 2018; Kjølholt et al., 2012; Magnusson et al., 2018; Zhu et al., 2016), and all but one were from closed-loop systems. No samples exceeded the IMO guidelines discharge criteria for nitrates, which at 60 mg/L at 45 t/MWh is equivalent to 2,700,000 mg/MWh. Given that there was only one value associated with open-loop discharges, it is not possible to compare discharge values between closed-loop and open-loop systems in detail. The median closed-loop discharge was approximately 125,000 mg/MWh. The sole open-loop discharge is 19,800 mg/MWh.

Nitrates and nitrites are essential for marine primary production, but an excess can accelerate eutrophication. Washwater discharges contain both nitrates and nitrites; however, the IMO guidelines cover only nitrates. The United States, in its 2013 VGP, requires ships to meet the same standard as the IMO guideline for nitrates, but it is the sum of nitrates and nitrites. Nevertheless, we have shown that scrubber discharges do not usually contain enough nitrates to exceed the limit in the IMO guidelines.

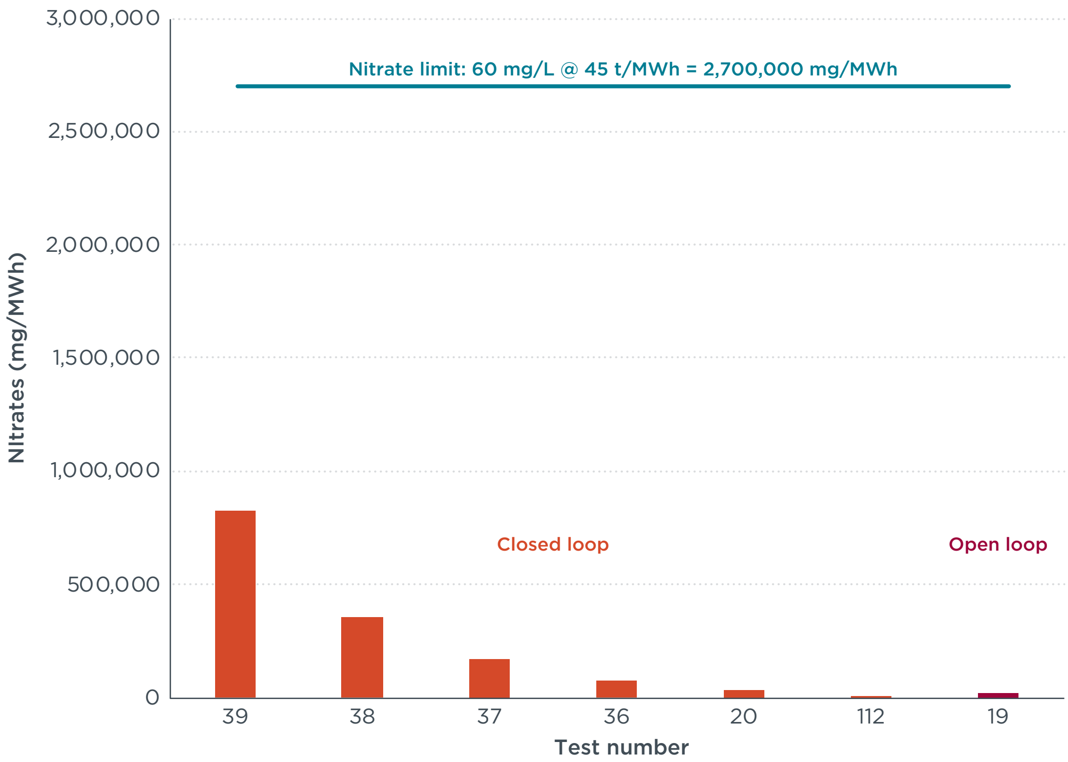
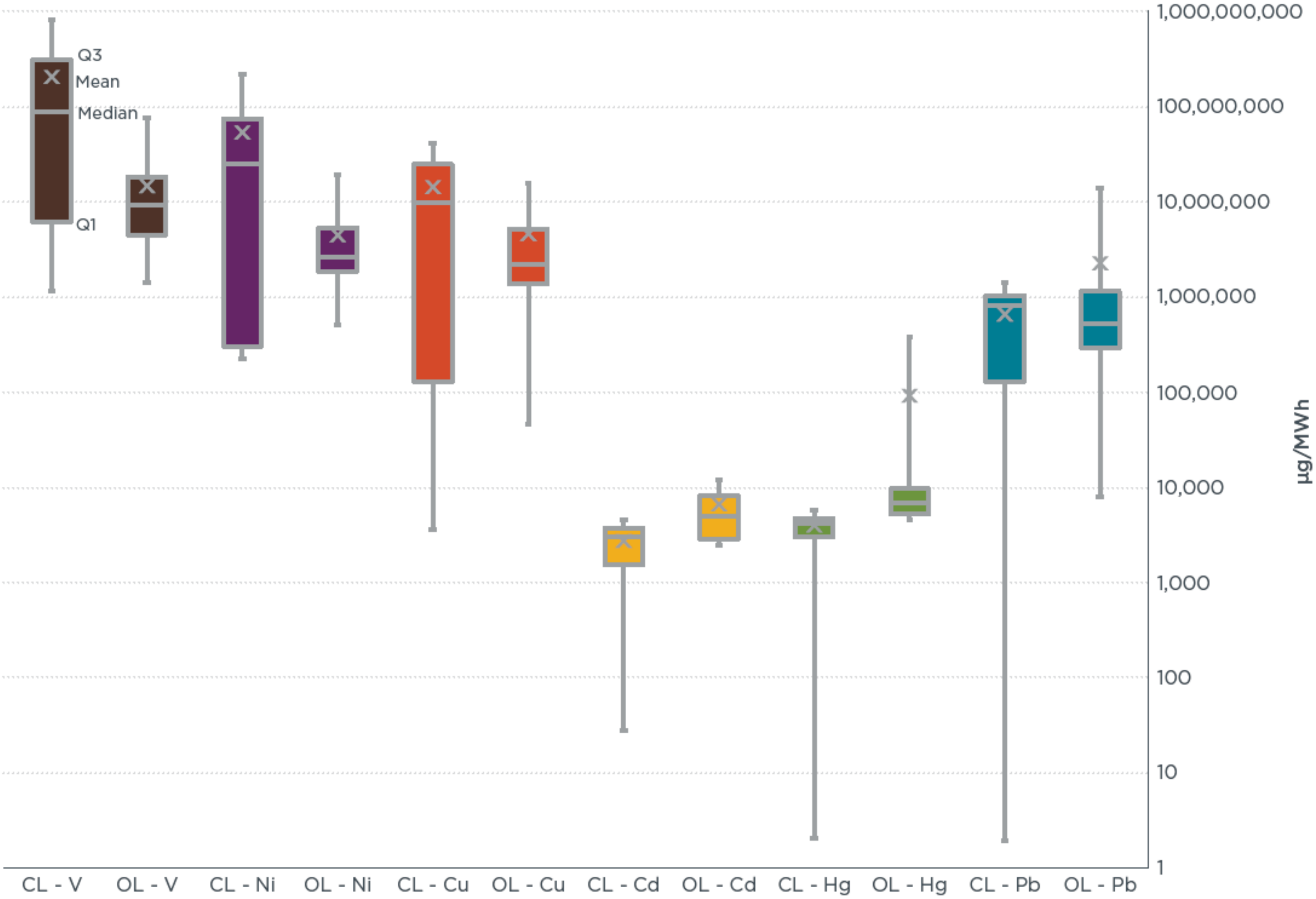


Figure 6. Nitrates in scrubber discharge water.

Heavy metals

We evaluated discharges of six heavy metals: vanadium, nickel, copper, cadmium, mercury, and lead. We found seven studies, representing 58 samples, that had reported values for at least one of these metals. Vanadium, which is found in HFO, was the most studied metal with 58 samples, 46 being from open-loop mode. As shown in Figure 7, vanadium had the highest average discharges of the metals studied, with closed-loop systems emitting more than open-loop, but the open-loop discharge values showed less variability. Nickel and copper displayed similar patterns of higher, more varying average values in closed-loop mode, but vanadium was discharged at significantly higher amounts than nickel and copper (note the log scale). Other metals, such as cadmium, mercury, and lead, were observed in smaller amounts, but had higher average discharges from open-loop scrubbers than closed loop. Open-loop discharges are more acidic, which could lead to larger amounts of dissolved heavy metals in the discharge water.

However, it appears that per MWh, closed-loop systems contribute greater mass of heavy metals than open-loop systems. With that said, additional work is needed to fully understand why closed-loop discharges exhibit greater variability. Currently there are no IMO guidelines for any heavy metal.



	CL - V	OL - V	CL - Ni	OL - Ni	CL - Cu	OL - Cu	CL - Cd	OL - Cd	CL - Hg	OL - Hg	CL - Pb	OL - Pb
Q1	6.2E+06	4.5E+06	3.1E+05	1.8E+06	1.3E+05	1.4E+06	1.5E+03	2.9E+03	3.0E+03	5.3E+03	1.3E+05	2.9E+05
Median	8.9E+07	9.3E+06	2.5E+07	2.6E+06	1.0E+07	2.2E+06	3.0E+03	5.0E+03	4.1E+03	6.8E+03	8.2E+05	5.2E+05
Q3	3.1E+08	1.8E+07	7.3E+07	5.3E+06	2.5E+07	5.2E+06	3.8E+03	8.3E+03	4.7E+03	9.8E+03	1.0E+06	1.1E+06
Mean	2.1E+08	1.5E+07	5.4E+07	4.4E+06	1.4E+07	4.5E+06	2.5E+03	6.1E+03	3.5E+03	8.4E+04	6.5E+05	2.2E+06

Figure 7. Heavy metal discharges (µg/MWh) for closed-loop (CL) and open-loop (OL) scrubbers, with values in the table. The box shows the interquartile range. The whiskers show the minimum and maximum values. The median and mean is marked by the X and the median is the horizontal line inside each box.

Table 9 includes recommended scrubber discharge water emission factors for each pollutant. They are based on rounded median values from the results presented in this section. Some emission factors are more certain than others. We found more data on pH, PAHs, and heavy metals, but less on turbidity and nitrates. The open-loop nitrate emission factor is based on one measurement and should be considered the least certain. On the other hand, the PAH_{phe} open-loop emission factor is based on 50 samples and should be considered the most certain. These emission factors can be used to get an understanding of the magnitude of water pollution from scrubbers, as well as trends over time. They will be particularly useful if paired with geospatial ship activity data so that the location and amount of discharges can be estimated. This could help determine the amount of pollution in ports, harbors, estuaries, rivers, critical habitats for marine life, Marine Protected Areas, Particularly Sensitive Sea Areas, and other areas of interest.

Table 9. Recommended scrubber discharge water emission factors

					Heavy metals (µg/MWh)					
Scrubber mode	**pH**	**PAH_{phe} (µg/MWh)**	**Turbidity (NTU)**	**Nitrates (mg/MWh)**	**Vanadium**	**Nickel**	**Copper**	**Cadmium**	**Mercury**	**Lead**
Closed loop	7.6	6,600	10	125,000	88,850,000	24,540,000	9,990,000	3,000	4,000	818,000
Open loop	5.6	119,000	1	20,000	9,310,000	2,590,000	2,180,000	5,000	7,000	519,000

CONCLUSIONS

This report assessed the impacts of scrubbers on air emissions and water pollution. Regarding air emissions, we found that scrubbers can substantially reduce SO_2 emissions, with emissions from ships using 2.6% sulfur HFO with a scrubber averaging 31% lower than 0.07% sulfur MGO. We also found that scrubbers seem to somewhat reduce CO emissions (-11% on average), although the mechanism by which this occurs deserves further investigation. For other pollutants, including CO_2, PM, and BC, using HFO with scrubbers results in higher emissions than MGO. Average CO_2 emissions were 4% higher using HFO with a scrubber compared with MGO. On a life-cycle basis, well-to-wake CO_2 emissions are expected to be 1.1% higher than using MGO. PM emissions from using HFO with a scrubber were approximately 70% higher than MGO, on average. BC emissions using HFO with a scrubber were expected to be 81% higher than using MGO in an MSD engine and more than four times higher than using MGO in an SSD engine. Emissions of NO_x were sometimes lower and sometimes higher after the scrubber; however, based on the studies reviewed, we found the average effect to be 0%. We do not expect scrubbers to have a significant direct impact on NO_x emissions because NO_x formation is more sensitive to other parameters, including combustion temperature.

Regarding water pollutants, we found that all scrubbers—open loop, closed loop, and hybrid—discharge water that is more acidic and turbid than the surrounding water. Additionally, all scrubbers emit nitrates, PAHs, and heavy metals. The acids that scrubbers emit contribute to ocean acidification. Discharge from open-loop scrubbers was typically more acidic than bleed-off water discharges from closed-loop systems. Turbid water degrades water quality and the suspended PM in turbid water can contain PAHs and heavy metals. We found that closed-loop bleed-off water was more turbid than open-loop discharges. We did not have enough information to determine which system—open or closed—emits more nitrates. Discharging nitrates contributes to acidification and can lead to eutrophication.

The amount of pollution that is discharged, as well as its ecological impacts, will depend on the characteristics of the inlet and receiving waters. Ships use scrubbers not only on the open ocean, but also in places with brackish and fresh water; in Canada, these include the St. Lawrence and Fraser estuaries, as well as the Great Lakes. Brackish and fresh waters are less alkaline than sea water, and this can affect the performance of the scrubbers. These waters may also already be contaminated by PAHs and heavy metals, meaning scrubber discharges will add additional pollution burdens to marine life. PAHs are carcinogenic and heavy metals are toxic, and both can accumulate in the water, sediments, and marine life. They bioaccumulate up the food chain and have been linked to cancer and immune system suppression in marine mammals including in killer whales and belugas. Open-loop systems emit substantially more PAHs than closed-loop systems, often orders of magnitude higher, whereas closed-loop systems tended to emit more heavy metals; this is an unexpected finding, given that closed-loop systems are meant to collect PM, which could include heavy metals, in onboard sludge tanks. One possible explanation is that the recirculating water collects more heavy metals before it is discharged as bleed-off. However, we found that the variability in closed-loop heavy metal discharges was greater than open-loop systems. Therefore, more work is needed to fully understand if open-loop or closed-loop systems emit different amounts of heavy metals.

In general, scrubber discharges from both open-loop and closed-loop systems usually comply with IMO guidelines. However, we question whether complying with the IMO guidelines should be taken as evidence that scrubbers are doing no harm to the aquatic environment. We discovered that the discharge criteria set out in IMO's guidelines were weakened at the very first opportunity. The first IMO scrubber guidelines were set in 2005 and did not include numeric discharge criteria but did state that pollutants should be eliminated or reduced to a level at which they are not harmful. Since then, the guidelines have only been weakened. The first numeric discharge criteria for pH, PAHs, turbidity, and nitrates were included in the 2008 guidelines, which were adopted by MEPC 57. The pH, PAH, and nitrate discharge criteria that were ultimately agreed to by MEPC 57 based on the outcomes of BLG 12 were substantially weaker than those proposed by the second intersessional BLG Working Group on Air Pollution (BLG-WGAP 2). Neither BLG 12 nor MEPC 57 gave any explanation for why these criteria were weakened from those proposed by the intersessional working group.

One could consider these results and conclude that the IMO guidelines simply need to be reviewed again and strengthened. However, we would argue that history has shown that the IMO guidelines were established at a limit that ensures that scrubber technologies can meet them. Given opportunities to strengthen the discharge criteria in 2009, 2015, and 2020, IMO member states declined, citing too little scientific evidence to revise them. The result is that the discharge criteria have not been strengthened since they were established. Meanwhile, the number of ships with scrubbers has grown exponentially, from three ships in 2008 to more than 4,300 in 2020. The guidelines ignore the cumulative effects of many ships operating and discharging in heavily trafficked areas, something to be expected given this rapid increase in the number of ships with scrubbers. Given that the IMO completed its most recent review of the guidelines at PPR 7 in 2020 and that MEPC will likely adopt them without further revision, we do not expect another opportunity to review and revise the discharge criteria at the IMO level for at least several years. During that time, thousands of ships will continue to use scrubbers that are designed to discharge acids, nitrates, solid particles, PAHs, and heavy metals to the marine environment, including in ports, harbors, estuaries, near shore areas, and busy shipping lanes where the combined effects could rapidly accumulate. This includes places like the Great Lakes, as well as British Columbia and the St. Lawrence estuary, where endangered species like the Southern Resident killer whale and belugas already suffer from high levels of contamination, including from PAHs and heavy metals.

The ICCT recommends that individual governments continue to take unilateral action to restrict or prohibit scrubber discharges from both open-loop and closed loop systems. We also recommend that the IMO focus on harmonizing rules for scrubber discharges including where, when, and even if those discharges should be allowed, and to do so with urgency. The IMO should consider prohibiting the use of scrubbers as a compliance option for newbuild ships and work to phase out scrubbers installed on existing ships. This is because we have found that using HFO with scrubbers is not equivalently effective at reducing air pollution compared to using lower sulfur fuels, such as MGO. Additionally, scrubbers of all kinds (open, closed, and hybrid) directly contribute to ocean acidification and water pollution, whereas lower sulfur fuels do not. Until then, we recommend that individual countries, including Canada, take immediate actions to protect their air and waters from scrubber emissions and discharges. These actions could include one or both of the following: (1) an immediate prohibition on using scrubbers to comply with the Canadian portion of the North American ECA because they are not equivalently effective at reducing air pollution as ECA-compliant fuels; (2) an immediate prohibition on all scrubber discharges in Canadian ports, internal waters, and territorial seas because they contribute to acidification and water pollution that can negatively affect marine life.

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