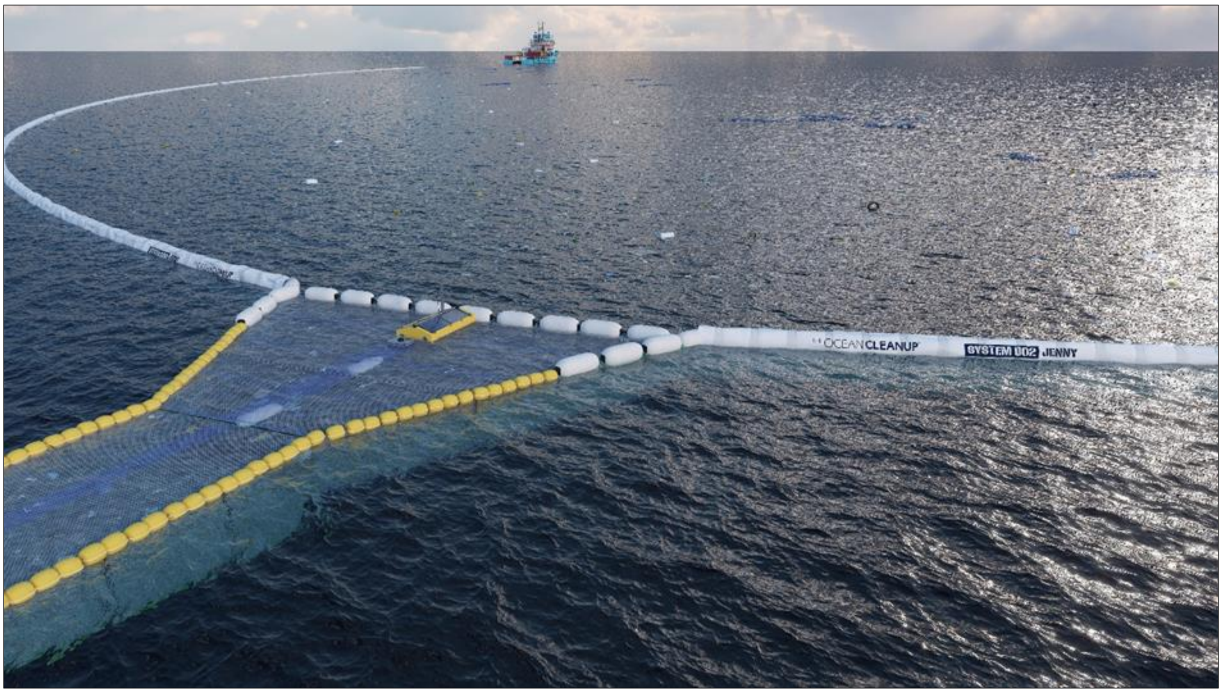
The Ocean Cleanup

Final Environmental Impact Assessment

12 July 2021



Prepared for:

The Ocean Cleanup
Batavierenstraat 15, 4-7th floor
3014 JH Rotterdam
The Netherlands

Prepared by:

CSA Ocean Sciences, Inc.
8502 SW Kansas Avenue
Stuart, Florida 34997
United States

THE OCEAN CLEANUP

DRAFT ENVIRONMENTAL IMPACT ASSESSMENT

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Internal review process					
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INT-01	04/20/2021	Initial draft for science review	J. Tiggelaar A. Lawson G. Dodillet K. Olen	B. Balcom R. Cady	K. Olsen
INT-02	04/24/2021	TE review	J. Tiggelaar K. Olen	K. Metzger	K. Olsen

Client deliverable			
Version	Date	Description	Project Manager Approval
01	04/27/2021	Draft Chapters 1-4	K. Olsen
02	05/07/2021	Combined deliverable	K. Olsen
03	05/17/2021	Incorporation of The Ocean Cleanup and Neuston Expert Comments	K. Olsen
FIN	07/09/2021	Incorporate legal comments and add additional 2 cruises	K. Olsen
FIN REV01	07/12/2021	Revised Final	K. Olsen

BACKGROUND

The Ocean Cleanup has developed a new Ocean System (S002) which is made by a Retention System (RS) comprising two wings of 391 m in length each and a Retention Zone (RZ), that will be towed by two vessels to collect buoyant plastic debris from the within the North Pacific Subtropical Gyre (NPSG) located roughly midway between California and Hawaii. The RS wings are designed to guide plastics greater than 10 mm in size into the RZ (**Figure ES-1**). The RS span can be adjusted between a maximum span of 700 m to a minimum span of 400 m for standard plastic collection operations.

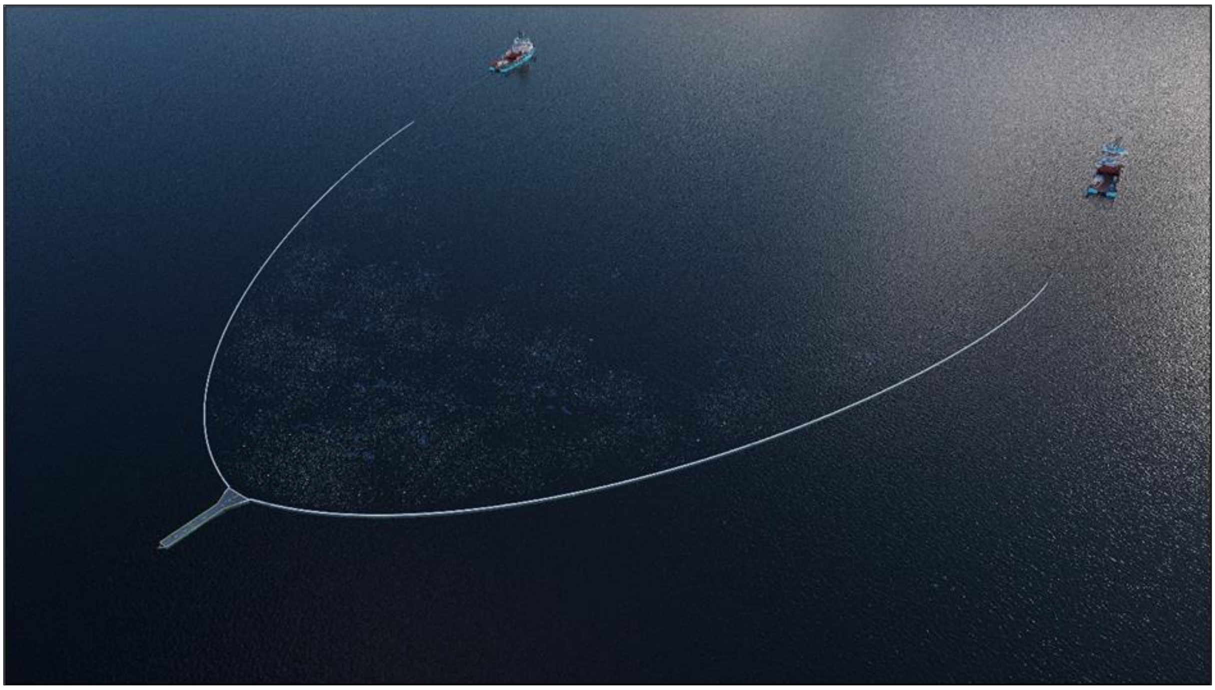

Figure ES-1. Towing lines (connected to each ship), Retention System (white wings and submerged net), Retention Zone (blue and yellow net attached to the back of the Retention System)

The Ocean Cleanup is planning two, but up to four, 6 week campaigns in the NPSG in a location approximately 2,250 km (1,215 nmi) from the Victoria-Vancouver, British Columbia area. Fabrication and assembly of The Ocean Cleanup System (OCS) has begun and will be completed for deployment in the Summer of 2021. S002 is modular in design and will be transported in 40-ft containers to Canada and later mobilized onto the *Maersk Tender* and/or *Maersk Trader* for transport to site.

PURPOSE AND NEED

The Ocean Cleanup voluntarily chose to conduct an Environmental Impact Assessment (EIA) to properly assess potential impacts and ensure that mitigation measures could be implemented to reduce or eliminate any substantial identified impacts. The deployment to the NPSG will not be by U.S. flagged vessels and will not be completed by U.S. citizens. All of the proposed activities will occur in international waters. Because no permits are required, no EIA is required. In the absence of regulatory requirements, this EIA was created to meet the 1999 International Association for Impact Assessment Principles of Environmental Impact Assessment Best Practices (IAIA, 1999).

EIA SUMMARY

The various components of the activities being proposed by The Ocean Cleanup have been evaluated for potential impacts to the biological, physical, chemical and social environment. A total of 17 resource areas were considered, including:

- Air Quality
- Water Quality
- Sediment Quality
- Plankton
- Neuston
- Fish and Fishery Resources
- Benthic Communities
- Marine Mammals
- Sea Turtles
- Coastal and Oceanic Birds
- Protected Areas
- Biodiversity
- Archaeological Resources
- Commercial and Military Vessels
- Human Resources, Land Use, and Economics
- Recreational Resources and Tourism
- Physical Oceanography

A preliminary screening was conducted to identify the resources at risk from the transit and deployment of S002 in the NPSG. In this preliminary analysis, the level of impact associated with each interaction was categorized as “potential impact for analysis” (e.g., a measurable impact to a resource is predicted) or “no impact expected” (i.e., no measurable impact to a resource is predicted). Several resources were identified as having no expected impacts from the proposed activities and were removed from further analysis. Resource areas that were screened out included air quality; sediment quality; water quality; benthic communities; biodiversity; archaeological resources, human resources, land use and economics; recreational resources and tourism; and physical oceanography. The remaining resource areas were characterized based on review and summarization of pertinent data sources, including peer-reviewed literature, government publications, and applicable datasets.

Biodiversity was included in the screening process and determined that there is not enough information at this time to fully address biodiversity impacts from the S002. After the up to four, 6 week-long campaigns, data collected during the campaign may be used, if feasible, in conjunction with existing Ecopath models, as well as any additional data from applicable scientific research studies, to develop a model specific for The Ocean Cleanup project. Application of these data within the framework of an Ecopath model may provide another tool to better evaluate any biodiversity impacts from The Ocean Cleanup activities. This information will be included in a Revised Final EIA.

Impact consequence and impact likelihood are two factors used to determine potential impact significance (**Figure ES-2**).

Determination of Impact Consequence

Impact consequence reflects an assessment of an impact’s characteristics on a specific resource (e.g., air quality and greenhouse gas contribution, benthic communities, etc.) arising from one or more impact-producing factors (IPFs). Impact consequence is determined regardless of impact likelihood. Impact consequence classifications include Positive (Beneficial), Negligible, Minor, Moderate, and Severe.

For negative impacts[1], the determination of impact consequence is based on the integration of three criteria: intensity, extent, and duration of the impact. These criteria are defined below; four levels of consequence can be attributed to a negative impact based on a rigorous analysis explained for each resource. When it is appropriate, calculations have been made to characterize quantitatively the intensity and/or the extent of the impacts. These calculations are explained for each of the resources concerned. Positive impacts[2] are noted, but their consequence is not qualified.

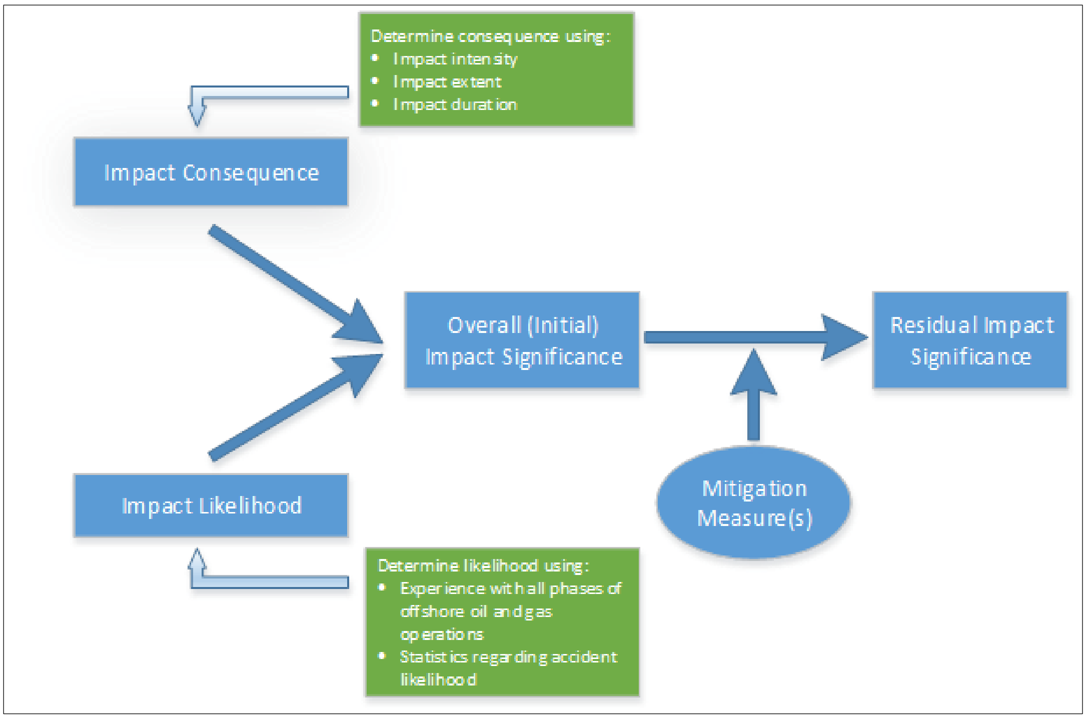

Figure ES-2. Impact assessment flow chart.

Intensity of an Impact

The intensity relates to the degree of disturbance associated with the impact and the alteration of the current state of the host environment. Three levels of intensity can be attributed[3]:

- **Low**: Small adverse changes unlikely to be noticed or measurable against background activities. For the social environment, changes may be noticed only by a few individuals;
- **Moderate**: Adverse changes that can be monitored and/or noticed but are within the scope of existing variability without affecting the resource's integrity or use in the environment. For the social environment, adverse change that affects several people, but not the entire community; or

[1] A negative impact is an impact where the change to the current situation of the resource is generally considered adverse or undesirable.

[2] A positive impact is an impact where the change to the current situation of the resource is generally considered better or desirable.

[3] The definitions presented here are general descriptions of the levels for each criterion. Not all resources have been included as examples, but specific explanations are provided in the assessment when needed.

- **High**: For the physical environment, extensive or frequent violation of applicable air or water quality standards/guidelines, or widespread contamination of sediments with hydrocarbons, toxic metals, or other toxic substances. For the biological environment, extensive damage to habitats to the extent that ecosystem functions and ecological relationships would be altered, or numerous deaths or injuries of a protected species and/or continual disruption of their critical activities. For the social environment, extensive adverse change that is far-reaching and widely recognized, it significantly limits the use of a resource by a community or a regional population, or its functional and safe use is seriously compromised. An impact potentially resulting in the death of one or more community members is also considered of high intensity.

Extent of an Impact

The geographic extent of an impact expresses how widespread the impact is expected to be. It represents the area that will be affected, directly or indirectly. An impact extent is classified by the following levels:

- **Immediate vicinity**: Limited to a confined space within the Area of Interest (AOI), generally within 2 km of the project activities;
- **Local**: The impact has an influence that goes beyond the AOI, but stays within a relatively small geographic area (i.e., generally about 5 to 20 km from the source of impact); or
- **Regional**: The impact affects a large geographical area, generally more than 20 km from the source of impact.

In general, the extent of all impacts to resources from The Ocean Cleanup project would be immediate vicinity, except for potential behavior modifications for marine mammals due to noise, which would be local, and for neuston, which would range from local to regional.

Duration of an Impact

The duration of an impact describes the length of time over which the effects of an impact occur. It is not necessarily the same as the length of time of an activity or an IPF as an impact can sometimes continue after the source of impact has stopped or the impact can be shorter if there is an adaptation. Therefore, this period can include the recovery period or the adaptation period of the affected resource. The duration of the impact can be:

- **Short term**: the impacts are felt continuously or discontinuously over a limited period, generally during the project period of activity, or when the recovery or adaptation period is less than a year; or
- **Long term**: the impacts are felt continuously or discontinuously beyond the life of the proposed project.

The duration for all impacts associated with The Ocean Cleanup project for this evaluation is expected to be short term, although the potential for long term impacts will be assessed (e.g., neuston).

Table ES-1 lists the combinations of criteria that have been used to describe impact consequence.

Table ES-1. Matrix of consequence determination for negative impacts.

Intensity	Extent	Duration	Consequence Criteria			
			Negligible	Minor	Moderate	Severe
Low	Immediate vicinity	Short term	●	-	-	-
	Local	Short term	●	-	-	-
	Regional	Short term	●	-	-	-
	Immediate vicinity	Long term	●	-	-	-
	Local	Long term	-	●	-	-
	Regional	Long term	-	●	-	-
Moderate	Immediate vicinity	Short term	-	●	-	-
	Local	Short term	-	●	-	-
	Regional	Short term	-	●	-	-
	Immediate vicinity	Long term	-	●	-	-
	Local	Long term	-	-	●	-
	Regional	Long term	-	-	●	-
High	Immediate vicinity	Short term	-	-	●	-
	Local	Short term	-	-	●	-
	Regional	Short term	-	-	●	-
	Immediate vicinity	Long term	-	-	●	-
	Local	Long term	-	-	-	●
	Regional	Long term	-	-	-	●

- = not applicable.

Likelihood of an Impact

The likelihood of an impact describes the probability that an impact will occur. The likelihood of impact occurrence was rated using the following categories:

- Likely (>50% likelihood);
- Occasional (10% to 49% likelihood);
- Rare (1% to 9% likelihood); and
- Remote (<1% likelihood).

Impacts are evaluated or predicted 1) prior to the implementation of mitigation measures; and 2) following implementation of these measures. Mitigation measures are identified based on industry best practice or international standards (e.g., MARPOL requirements) or measures deemed applicable and practicable by The Ocean Cleanup. Impacts that remain after adoption or implementation of mitigation measures are described as residual impacts. To summarize the overall significance of each impact, impact consequence and likelihood were combined using professional judgment and a risk matrix, as shown in **Table ES-2**. According to this matrix, the overall impact significance for biological and social negative impacts using a numeric, descriptive, and color-coded approach is rated as follows:

- 1 – Negligible;
- 2 – Low;
- 3 – Medium; and
- 4 – High.

Table ES-2. Matrix combining impact consequence and likelihood to determine overall impact significance.

Likelihood vs. Consequence		← Decreasing Impact Consequence				
		Beneficial	Negligible	Minor	Moderate	Severe
Decreasing Impact Likelihood ↓	Likely	Beneficial (no numeric rating applied)	1 – Negligible	2 – Low	3 – Medium	4 – High
	Occasional		1 – Negligible	2 – Low	3 – Medium	4 – High
	Rare		1 – Negligible	1 – Negligible	2 – Low	4 – High
	Remote		1 – Negligible	1 – Negligible	2 – Low	3 – Medium

Impacts from routine operations resulting from the proposed activities are expected to occur based on a series of impact producing factors, including:

- S002 – Entanglement/Entrapment
- S002 – Attraction/Ingestion of Plastics
- Vessel – Physical Presence/Strikes
- Noise and Lights
- Loss of Debris

The Environmental Impact Assessment also addressed potential impacts associated with an accidental fuel spill. Resources potentially affected by each impact producing factor were subsequently evaluated. The impact assessment process involved: 1) an initial determination of impact, without any mitigation (i.e., potential impacts); 2) an identification and application of appropriate mitigation measures; and 3) a determination of impact after mitigation was applied (i.e., residual impact).

Impacts rated Medium or High were considered primary candidates for mitigation, while those rated Negligible or Low were of secondary importance from a mitigation perspective. In application, mitigation measures were considered for all impacts, regardless of impact level. The initial analysis of routine operations (i.e., prior to application of mitigation measures) produced impact determinations that were predominately in the Negligible or Low categories, with several identified as Medium to High for plankton and neuston and Medium for fish and fisheries for the up to four, 6 week campaigns of S002. A comprehensive discussion of the mitigation measures and corporate/subcontractor policies that The Ocean Cleanup will follow during their proposed activities is presented under separate cover in an Environmental Management Plan.

Impacts from an accidental fuel spill were identified based on the accidental release of diesel fuel. Diesel fuel released into the marine environment undergoes rapid weathering, including evaporation and dissolution. Given the relatively small potential spill volume and weathering factors, the impacts to various resources from a fuel spill release were routinely rated Negligible or Low. Impacts from an accidental diesel fuel spill are expected to be localized and relatively short term (due to its high volatility and dispersibility). A tabular summary of impacts from routine operations and an accidental fuel spill is presented in **Table ES-3**. When proper mitigation measures, maritime regulations, and industry best practices are applied, the significance of potential impacts of the proposed activities will generally be Negligible or Low. Moreover, The Ocean Cleanup estimates that approximately 40 tons of plastics would be collected during each 6-week campaign which would have long-term positive impacts as a result of removing floating plastic from the NPSG will likely provide a beneficial impact to biological resources in the area.

Table ES-3. Summary of impacts from routine operations and an accidental fuel spill from the proposed activities.

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Long-Term Impacts					
Plastic Removal by S002					
All Resources Except Plankton and Neuston	Reduction in entanglements, ingestion, and contamination of every biological and social resource by means of plastic debris removal from the North Pacific	**Beneficial**	Not applicable.	Not Applicable	**Beneficial**
Routine Operations					
S002 – Entanglement/Entrapment					
Plankton/Neuston	• Entanglement in S002 or accumulated debris resulting in injury or death	Intensity: Moderate to High Extent: Local to Regional Duration: Short Term Consequence: Moderate Likelihood: Likely Significance: 3 – Medium to Significance: to 4 – High	• **Escape aids** – System equipped with a remote triggered quick release for the end of the Retention Zone (RZ) to free potential clogs*; and • **Net resting** – the net will be allowed to rest 30 to 60 minutes prior to retrieval to give some species time to escape.	Reduces Intensity and Likelihood	2 – Low to 4 – High

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Fish and Fishery Resources	• Entanglement in S002 or accumulated debris resulting in injury or death	Intensity: High Extent: Immediate Vicinity Duration: Short Term Consequence: Moderate Likelihood: Likely Significance: 3 – Medium	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ with specific darker yellow netting used for escape routes and use of white flashing LED lights to enhance detectability of the System. • **Vessel operations** – Towing vessels in the North Pacific Subtropical Gyre (NPSG) will travel as extremely slow speeds (0.5–2.5 knots). • **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled fish*; the net will be allowed to rest 30 to 60 minutes prior to retrieval to give fish time to escape; use of a Fyke Opening just after the entrance to the Retention Area. • **Visual monitoring** – Monitoring during the project will identify fish that may enter the S002: ○ Use of one forward- and one backwards-looking Thermal/RGB camera system; and ○ Multiple above and underwater cameras will be installed above and inside the RZ.	Reduces Intensity and Likelihood	2 – Low

Table ES-3. (Continued).

<table>
<tr><th>Resource Affected</th><th>Description of Potential Impact</th><th>Impact Determination Prior to Mitigation</th><th>Mitigation Measure(s)</th><th>Component of Impact Consequence Affected by Mitigation</th><th>Residual Impact</th></tr>
<tr><td rowspan="2">Marine Mammals</td><td rowspan="2">• Entanglement in S002 or accumulated debris resulting in injury or death</td><td rowspan="2">Intensity: High
Extent: Immediate Vicinity Regional (Protected Species)
Duration: Short Term
Consequence: Moderate
Likelihood: Remote
Significance: 2 – Low</td><td rowspan="2">• Routine debris extraction – Routinely remove accumulated debris (e.g., plastics, fishing nets) between 1.2 to 2 weeks from S002 RZ.
• Visual monitoring – Monitoring during the project will identify marine mammals that may be near tow vessels with:
  o PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
  o Multiple above and underwater cameras will be installed above and inside the RZ.
• Visual cues – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.
• Acoustic deterrent – Banana pingers attached to the system to deter approach of some marine mammals.
• Escape aids – System equipped with a remote triggered quick release for the end of the RZ to free entangled marine mammals* and the net will be allowed to rest 30 to 60 minutes in case of accidental entrapment and any time prior to retrieval to give marine mammals time to escape.</td><td>Reduces Intensity and Likelihood</td><td>1 – Negligible</td></tr>
<tr><td>Reduces Likelihood</td><td>2 – Low (Protected Species)</td></tr>
</table>

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Marine Mammals (cont'd)			• **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 50 cm to guarantee access to air for marine mammals. • **Rescue of animals** – Rescue attempts of entangled marine mammals in distress may be attempted according to the Environmental Management Plan.	Reduces Likelihood	2 – Low (Protected Species)

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Sea Turtles	• Entanglement or entrapment with S002 or accumulated debris	Intensity: High Extent: Regional Duration: Short Term Consequence: Moderate Likelihood: Rare Significance: 2 – Low	• **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near tow vessels with: o PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and o Multiple above and underwater cameras will be installed above and inside the RZ. • **Visual cues** – Use of white flashing LED lights to enhance detectability of the System. • **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled sea turtles* and the net will be allowed to rest 30 to 60 minutes in case of accidental entrapment and any time prior to retrieval to give sea turtles time to escape* • **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 50 cm to guarantee access to air for sea turtles. • **Routine debris extraction** – Routinely remove accumulated debris (e.g., plastics, fishing nets) approximately every 1.2 to 2 weeks from S002 RZ. • **Rescue of animals** – Rescue attempts of entangled sea turtles in distress may be attempted according to the Environmental Management Plan.	Reduces Likelihood	2 – Low

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Coastal and Oceanic Birds	• Entanglement in S002 or accumulated debris resulting in injury or death	Intensity: High Extent: Immediate Vicinity Duration: Short Term Consequence: Moderate Likelihood: Rare Significance: 2 – Low	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System. • **Escape aids** – System equipped with a remote triggered quick release for the end of RZ to free entangled seabirds* and the net will be allowed to rest 30 to 60 minutes prior to retrieval to give seabirds time to escape. • **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 50 cm to guarantee access to air for seabirds.	Reduces Intensity and Likelihood	1 – Negligible
S002 – Attraction/Ingestion of Plastics					
Plankton/Neuston	• Ingestion of congregated plastics resulting in injury or death	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Likely Significance: 2 – Low	• Mitigation measures not feasible and still meet the goal of the project.	None	2 – Low
Fish and Fishery Resources	• Attraction to S002 • Ingestion of congregated plastics resulting in injury or death	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Likely Significance: 2 – Low	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.	Reduces Likelihood	2 – Low

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Marine Mammals	• Attraction to S002 • Ingestion of congregated plastics resulting in injury or death	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Remote Significance: 1 – Negligible	• **Visual monitoring** – Monitoring during the project will identify marine mammals that may be near tow vessels with: ○ PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and ○ Multiple above and underwater cameras will be installed above and inside the RZ. • **Visual cues** – Use of colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System. • **Acoustic deterrent** – Banana pingers attached to the system to deter approach of some marine mammals	Reduces Intensity and Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Sea Turtles	• Attraction to S002 • Ingestion of congregated plastics resulting in injury or death	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Occasional Significance: 2 – Low	• **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near tow vessels with: ○ PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and ○ Multiple above and underwater cameras will be installed above and inside the RZ. • **Visual cues** – Use of white flashing LED lights to enhance detectability of the System. • **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled sea turtles* and the net will be allowed to rest prior to retrieval to give sea turtles time to escape. • **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 50 cm to guarantee access to air for sea turtles. • **Routine debris extraction** – Routinely remove accumulated debris (e.g., plastics, fishing nets) approximately every 1.2 to 2 weeks from S002 RZ. • **Rescue of animals** – Rescue attempts of entangled sea turtles in distress may be attempted according to the Environmental Management Plan.	Reduces Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Coastal and Oceanic Birds	• Attraction to S002 • Ingestion of congregated plastics resulting in injury or death	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Occasional Significance: 2 – Low	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.	Reduces Intensity and Likelihood	1 – Negligible
Vessel – Physical Presence/Strikes					
Fish and Fishery Resources	• Attraction to vessels and strike resulting in injury or death	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Remote Significance: 1 – Negligible	• None recommended	None	1 – Negligible
Marine Mammals	• Injury or mortality resulting from a vessel collision with a marine mammal	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Remote Significance: 1 – Negligible	• **Visual monitoring** – Monitoring during the project will identify marine mammals that may be near tow vessels with: ○ PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and ○ Multiple above and underwater cameras will be installed above and inside the RZ. • **Vessel operations** – ○ Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots); ○ Towing vessels in the NPSG will travel as extremely slow speeds (0.5-2.5 knots); and ○ Vessels will maintain a watch for marine mammals when travelling to and from the NPSG.	Reduces Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Sea Turtles	• Injury or mortality resulting from a vessel collision with a sea turtle	Intensity: High Extent: Immediate Vicinity Duration: Short Term Consequence: Moderate Likelihood: Rare Significance: 2 – Low	• **Vessel operations** – Vessel speeds will be kept to a minimum for specific operations as follows: ○ Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots); ○ Towing vessels in the NPSG will travel as extremely slow speeds (0.5–2.5 knots); and ○ Debris collection vessels will maintain a watch for sea turtles and when travelling to and from the NPSG. • **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near vessels with: ○ Crew member PSOs during transit; and ○ PSOs during operations and use of one forward-looking Thermal/RGB camera system.	Reduces Intensity and Likelihood	1 – Negligible
Coastal and Oceanic Birds	• Injury or mortality resulting from a vessel collision with a bird due to attraction from lights	Intensity: High Extent: Immediate Vicinity Duration: Short Term Consequence: Moderate Likelihood: Rare Significance: 2 – Low	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.	Reduces Likelihood	1 – Negligible
Protected Areas	• Disturbance of wildlife in marine protected areas from vessel transit	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Rare Significance: 1 – Negligible	• **Strategic routing** –Vessel will avoid protected areas when practicable; and • **Vessel operations** – Vessel speeds will be kept to a minimum for transit as vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots) and obey all separation scheme restrictions.	Reduced Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Commercial and Military Vessels	• Temporary increase in vessel traffic	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Likely Significance: 1 – Negligible	• **Vessel operations** – Vessel speeds will be kept to a minimum for specific operations as follows: ○ Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots); and ○ Towing vessels in the NPSG will travel as extremely slow speeds (0.5–2.5 knots). • **Monitor notifications** – Vessels will monitor NOTSHIP notifications prior to and during transit from the Port.	None	1 – Negligible
Noise and Lights					
Plankton/Neuston	• Behavioral modifications (e.g., suppress diel migration, attraction to system) from tow vessels and light	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Likely Significance: 2 – Low	• **Limit lighting** – To the extent practicable blackout of vessel at night to avoid attracting species that undergo diel vertical migrations. Navigational lights on the system will flash intermittently to reduce shining light in the water at night.	Reduces Likelihood	2 – Low
Fish and Fishery Resources	• Behavioral modifications (e.g., evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels)	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Occasional Significance: 1 – Negligible	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. The sound generated by banana pingers is localized and is well above the hearing ranges of fish.	Reduces Intensity and Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
	• Attraction to tow vessels and lights	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Likely Significance: 2 – Low	• **Limit lighting** – Lights will be limited at night to the extent practicable. Navigational lights on the system will flash intermittently to reduce shining light in the water at night.	Reduces Likelihood	2 – Low
Marine Mammals	• Behavioral modifications (e.g., evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels)	Intensity: Low Extent: Local Duration: Short Term Consequence: Negligible Likelihood: Occasional Significance: 1 – Negligible	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. • **Visual cue/Acoustic deterrent** – Banana pingers will be used to potentially deter porpoises and high frequency hearing dolphins away from the system.	Reduces Intensity and Likelihood	1 – Negligible
Sea Turtles	• Behavioral modifications (e.g., diving, evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels) • Attraction to tow vessels and light	Intensity: Low Extent: Local Duration: Short Term Consequence: Negligible Likelihood: Occasional Significance: 1 – Negligible	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. Sound generated by banana pingers is localized and well above the hearing ranges of sea turtles. • **Visual cue** – Use of white flashing LED lights to enhance detectability of the System. • **Acoustic deterrent** – Sound generated by banana pingers is localized and will not propagate far. • **Minimize night-time deck lighting** – The level of lights onboard the vessels will be kept as low as reasonably practicable to maintain a safe work environment at night.	Reduces Intensity and Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Coastal and Oceanic Birds	• Behavioral modifications (e.g., diving, evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels)	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Occasional Significance: 1 – Negligible	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable.	Reduces Likelihood and Intensity	1 – Negligible
	• Attraction to tow vessels and light	Intensity: High Extent: Immediate Vicinity Duration: Short Term Consequence: Moderate Likelihood: Rare Significance: 2 – Low	• **Limit lighting** – Lights will be limited at night to the extent practicable. Navigational lights on the system will flash intermittently to reduce shining light in the water at night.	Reduces Likelihood and Intensity	1 – Negligible
Loss of Debris					
Marine Mammals	• Entanglement with, or ingestion of, debris accidentally lost	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Remote Significance: 1 – Negligible	• **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plans, potentially reducing the likelihood of occurrence.	Reduces Likelihood	1 – Negligible
Sea Turtles	• Entanglement with, or ingestion of, debris accidentally lost	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Remote Significance: 1 – Negligible	• **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plans, potentially reducing the likelihood of occurrence.	Reduces Intensity and Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Coastal and Oceanic Birds	• Entanglement with, or ingestion of, debris accidentally lost	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Remote Significance: 1 – Negligible	• **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plans, potentially reducing the likelihood of occurrence.	Reduces Intensity	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Accidental Fuel Spill					
Plankton/Neuston	• Exposure to diesel fuel including ingestion	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Rare Significance: 1 – Negligible	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – Contractor will ensure that a SOPEP is in place on towing, monitoring, and debris collection vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels. • **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization and during the time at sea, if necessary. Fuel hoses will be equipped with dry-break couplings. Any re-fueling required will only be undertaken in safe working weather conditions and good lighting. • **No re-fueling at sea** – No re-fueling will occur at sea. • **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.	Reduces Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Fish and Fishery Resources	• Hydrocarbon contamination from an accidental fuel spill	Intensity: Low Extent: Immediate Vicinity Duration: Short Term Consequence: Negligible Likelihood: Rare Significance: 1 – Negligible	• **Same as above** – SOPEP, spill equipment on board, fuel transfer protocols, no re-fueling at sea, and reporting procedures.	Reduces Likelihood	1 – Negligible
Marine Mammals	• Diesel fuel exposure, including inhalation of vapors, ingestion, fouling of baleen	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Remote Significance: 1 – Negligible	• **Same as above** – SOPEP, spill equipment on board, fuel transfer protocols, no re-fueling at sea, and reporting procedures.	Reduces Likelihood	1 – Negligible
Sea Turtles	• Diesel fuel exposure, including inhalation of vapors, ingestion	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Remote Significance: 1 – Negligible	• **Same as above** – SOPEP, spill equipment on board, fuel transfer protocols, no re-fueling at sea, and reporting procedures.	Reduces Likelihood	1 – Negligible

Table ES-3. (Continued).

Resource Affected	Description of Potential Impact	Impact Determination Prior to Mitigation	Mitigation Measure(s)	Component of Impact Consequence Affected by Mitigation	Residual Impact
Coastal and Oceanic Birds	• Diesel fuel exposure, including inhalation of vapors, ingestion	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Rare Significance: 1 – Negligible	• **Same as above** – SOPEP, spill equipment on board, fuel transfer protocols, no re-fueling at sea, and reporting procedures.	Reduces Likelihood	1 – Negligible
Protected Areas	• Diesel fuel exposure, fouling of habitat	Intensity: Moderate Extent: Immediate Vicinity Duration: Short Term Consequence: Minor Likelihood: Remote Significance: 1 – Negligible	• **Same as above** – SOPEP, spill equipment on board, fuel transfer protocols, no re-fueling at sea, and reporting procedures.	Reduces Likelihood	1 – Negligible

* Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

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Acronyms and Abbreviations

µPa	micropascal
ABNJ	area beyond national jurisdiction
ADD	Acoustic Deterrent Device
AHS	Acoustic Harassment Device
AIS	Automatic Identification System
BOEM	Bureau of Ocean Energy Management
CCS	California Current System
CEPA	Canadian Environmental Protection Act
CMS	Cameral Monitoring System
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSA	CSA Ocean Sciences Inc.
dB	decibels
DP	dynamic position
DPS	distinct population segment
EEZ	Exclusive Economic Zone
EFH	Essential fish habitat
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
FAD	fish aggregating device
GPGP	Great Pacific Garbage Patch
GPS	global positioning system
GTTS	global training tracking system
HDPE	High density polyethylene
IAIA	International Association for Impact Assessment
IBA	Important Bird Area
IHA	incidental harassment authorization
IMO	International Maritime Organization
IPF	impact producing factor
ITA	incidental take authorization
IUCN	International Union for Conservation of Nature
MARPOL	International Convention for the Prevention of Pollution from Ships
MOU	Memorandum of Understanding
MPA	Marine Protected Area
MRU	motion reference unit
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPP	net primary production
NPSG	North Pacific Subtropical Gyre
NTM	Notice to Mariners
PAM	Passive Acoustic Monitoring
PSO	Protected Species Observer
RS	Retention system
PTS	permanent threshold shift
RZ	Retention zone
SARA	Species at Risk Act
SEL	sound exposure level
SOPEP	Shipboard Oil Pollution Emergency Plan
SPL	root-mean-square sound pressure level
TTS	temporary threshold shift
U.S.	United States
USEPA	United States Environmental Protection Agency

1.0 Introduction

The Ocean Cleanup has developed a new concept for the Ocean System called S002 to collect buoyant plastic debris from the North Pacific Subtropical Gyre (NPSG). There are multiple areas where the debris accumulates, and The Ocean Cleanup is focusing on the area known as the Great Pacific Garbage Patch (GPGP) which is located roughly midway between California and Hawaii (**Figure 1-1**).

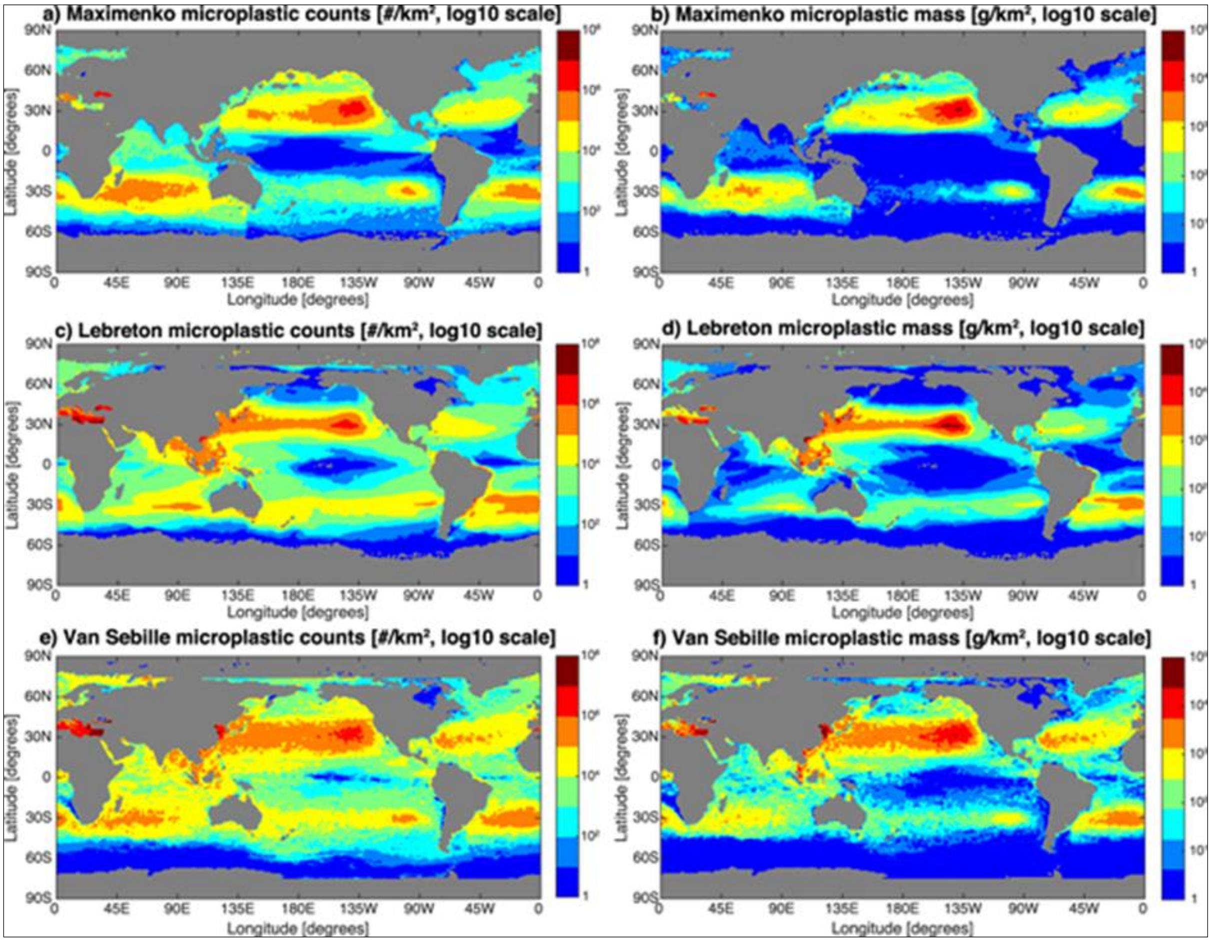


Figure 1-1. Results of computer modeling showing estimated density of microplastic contamination (from: van Sebille E., et al., 2015).

The Ocean Cleanup is planning two 6-week campaigns in the NPSG in a location approximately 2,250 km (1,215 nmi) from Victoria- Vancouver Island British Columbia; however, this could extent to up to four, 6-week campaigns depending on the results of the initial two campaigns. This Environmental Impact Assessment (EIA) presents the existing environmental conditions of the area that may be potentially impacted by the proposed project which includes a transiting from the Victoria area to the NPSG, followed by operations within the NPSG, and return to the Victoria Port for offloading. The EIA provides a description of the deployment and the planned operational scenarios within the NPSG and an assessment of potential environmental impacts that may result from operations together with recommendations to manage, mitigate, and monitor those impacts. The EIA is organized as follows:

- The **Executive Summary** is a short, non-technical summary of the project that briefly describes the baseline environment, the risk assessment methodology, potentially significant impacts, and mitigation measures.

- **Chapter 1.0**, **Introduction**, presents the project, including objectives, location, and scheduling. This chapter discusses the purpose, scope, and organization of the EIA.

- **Chapter 2.0**, **Project Description**, provides a detailed narrative of the proposed activities, the waste and emissions that may be associated with such a project, and the purpose of the project. Planned activities that may affect the environment are described in sufficient detail to support impact assessment.

- **Chapter 3.0**, **Legislative and Regulatory Environment**, identifies and describes the national and international laws, regulations, guidelines, protocols and standards that were considered as potentially applicable to the proposed project. This chapter summarizes specific permitting requirements that were considered in relation to the proposed project.

- **Chapter 4.0**, **Description of the Existing Environment**, characterizes the conditions of the project area environment in terms of the physical, chemical, and biological components. This chapter presents key information needed to understand the environmental setting, identify valued ecosystem components, and assess impacts. This chapter also provides a preliminary screening of resources to eliminate resources with little or no potential for adverse or significant impact from the detailed analysis. The text is organized as follows:
    - Preliminary Screening of Activities and Affected Resources;
    - Data Sources;
    - Biological Environment; and
    - Social Environment.

- **Chapter 5.0**, **Potential Environmental Impacts**, identifies and assesses the potential environmental impacts from this proposed project, both beneficial and negative. The chapter includes the basis for impact designation, impacts from routine operations, and impacts from potential accidents or upsets. Cumulative impacts are also discussed.

- **Chapter 6.0, Conclusion,** summarizes the findings of the EIA.

- **Chapter 7.0**, **Literature Cited**, lists all published and unpublished data sources in this EIA.

- **Appendix**, presents technical data used in support of the EIA.

2.1 PROJECT OVERVIEW

In 2018 and 2019, The Ocean Cleanup built and tested the first Ocean Cleanup System (System 001) and a second iteration (S001/B), two passive drifting systems that collected floating plastics in the top 3 m (9.8 ft) of the ocean surface. System 001 comprised a 600-meter-long U-shaped floating barrier with an attached screen. It was designed to be a passively drifting system driven by surface currents and wind; no engines or other propulsion systems were present. S001/B was very similar but smaller (140-meter long U shaped barrier) and featured with the possibility to modify the system by adding a drift anchor or wind capturing floating modules, in addition to a fully detachable screen and plastic retention zone. While System 001 and S001/B confirmed the concept's ability to concentrate and collect plastic debris, S002 was created to incorporate the lessons learned from the previous deployments and improve upon the existing design to further advance the system design and operation (**Figure 2-1**).

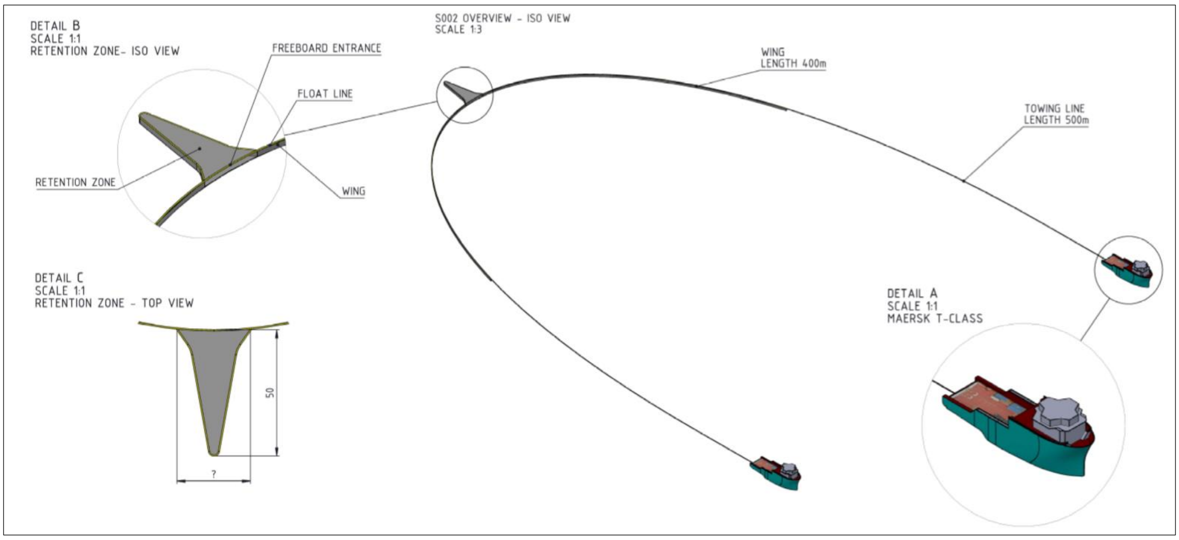


Figure 2-1. Ocean Cleanup Retention System S002 conceptual design.

2.1.1 The Ocean Cleanup System Design

The Ocean Cleanup has developed a Retention System (RS) comprising two wings of approximately 800 m in length and a Retention Zone (RZ). Based on the current system design (**Image 2-1**), S002 comprises a Retention System (RS), comprising two 391-m wings, an RZ (**Figure 2-2** and **Image 2-2**), and towing lines. The RS span can be adjusted depending on the intended operation mode: gathering mode allows for a maximum span of up to 700 m to cover a large area to capture plastic between the wings and will allow plastic transport along the wings to the RZ; the nominal mode has a span of 500 m, which will be the standard operational mode and has the optimum factor of span to length; and minimum capturing mode has a span of 195 m for vessel safety. During operations, The Ocean Cleanup will determine the span distance that allows for high quantity of plastics to travel to the RZ. The RS wings are designed to gather and guide plastics greater than 10 mm in size into the RZ, prevent underflow, prevent overtopping, minimize bycatch, and limit drag. The wing design parameters are detailed in **Table 2-1**. The wings have a modular design allowing them to fit onto one T-class vessel deck (the modules fit into 40'containers) and can be easily connected to the towing rigging. Each wing module length is 23 m, and 17 modules comprise one wing. The wings are composed of a float line, ballast line, and the screen attached between the float and ballast lines (**Figure 2-3**). The float line consists of single heavy duty inflatable fenders with a permeable cover at a height of 0.5 m above the water. Although the float line has a survivability of 5 years, it has a modular design that can be replaced offshore in case of damage and can be easily stacked for storage in containers and on deck. The 10-mm × 10 mm Dyneema® netting comprising the wings has a constant 3 m deep. The ballast line, used to keep the wings straight, the screen in tension and limit drag resistance as much as possible, consists of chain wrapped in a fire hose and weighs 6 kg m^{-1}. Like the float lines, the ballast lines are modular in design and can be replaced, modified, and if needed, removed. The wing to RZ connection is a smooth transition, leading the plastic into the RZ to prevent plastic overtopping, underflow, and prevent plastics from being pushed away (**Image 2-3**). The connection is deployable via the vessel roller and is easily connected/disconnected onboard the vessel. The assembled S002 will be concave shaped, which will be maintained with towing lines 500 m in length. The wings are easily connected to towing rigging. The RS design will allow the integration of, and provide stability for, 10 GPS trackers (supplied by GTTS), 10 motion reference units (MRUs), 2 radar reflectors, 10 lanterns, 7 banana pingers (1 at the entrance of the RZ and 3 on each wing), and 22 white flashing deterrent lights placed 46 m apart along the system wings and at the entrance of the RZ. The banana pingers utilize randomized pings with harmonics to prevent habituation that operate between frequencies of 50kHz and 120 kHz at a sound level of 145dB ± 3dB re 1 µPa m.

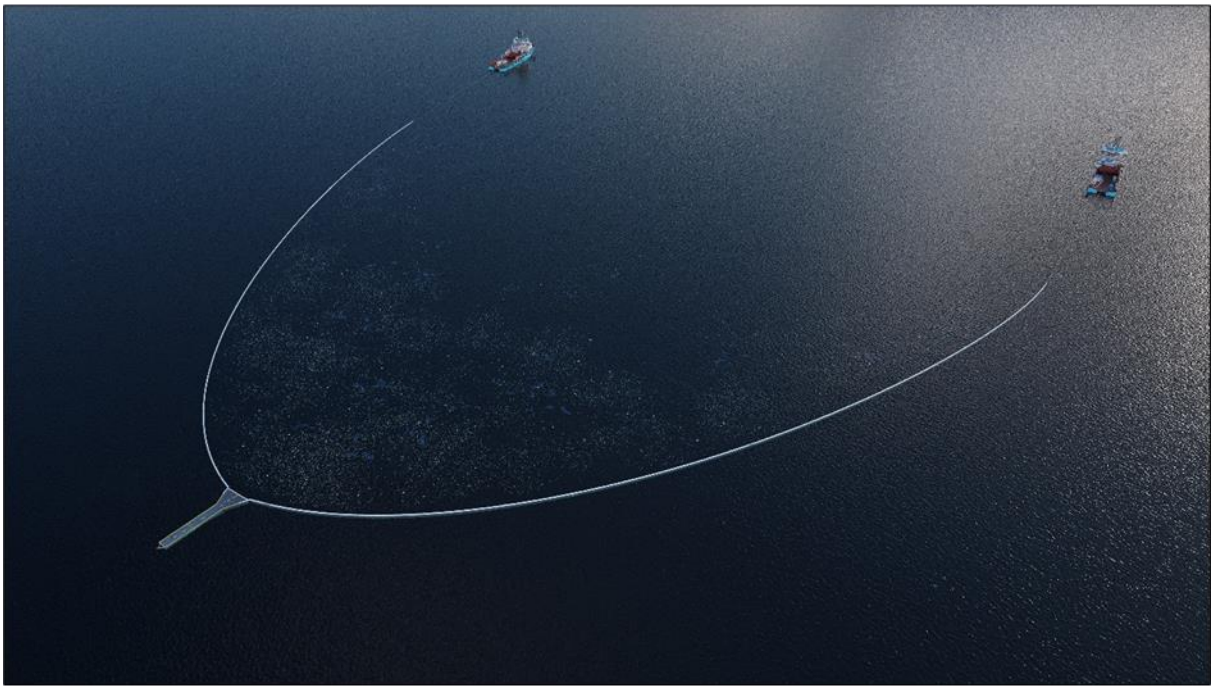
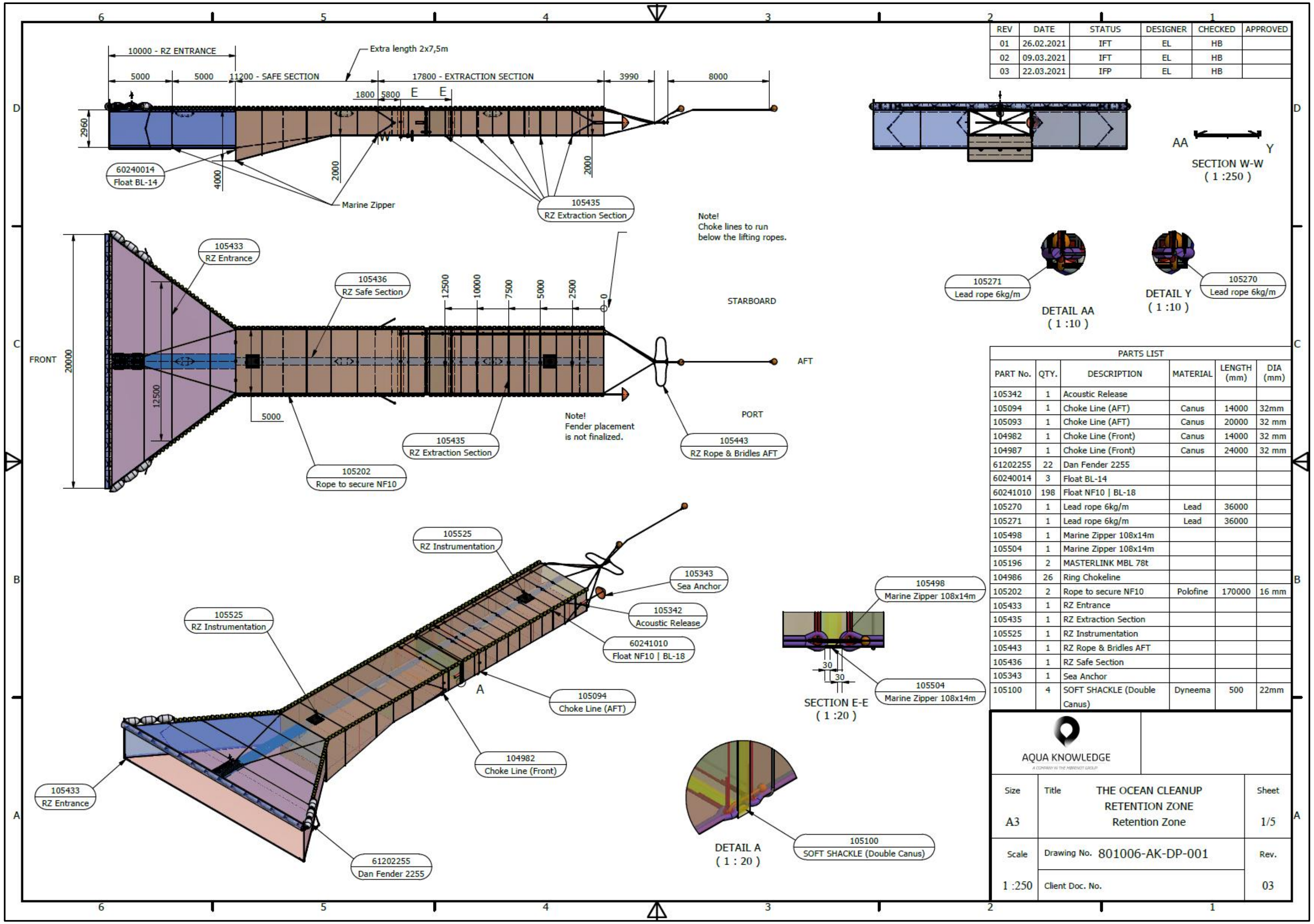


Image 2-1. Towing lines (connected to each ship), Retention System (white wings and submerged net), Retention Zone (blue and yellow net attached to the back of the Retention System).



REV	DATE	STATUS	DESIGNER	CHECKED	APPROVED
01	26.02.2021	IFT	EL	HB	
02	09.03.2021	IFT	EL	HB	
03	22.03.2021	IFP	EL	HB	

PARTS LIST					
PART No.	QTY.	DESCRIPTION	MATERIAL	LENGTH (mm)	DIA (mm)
105342	1	Acoustic Release			
105094	1	Choke Line (AFT)	Canus	14000	32mm
105093	1	Choke Line (AFT)	Canus	20000	32 mm
104982	1	Choke Line (Front)	Canus	14000	32 mm
104987	1	Choke Line (Front)	Canus	24000	32 mm
61202255	22	Dan Fender 2255			
60240014	3	Float BL-14			
60241010	198	Float NF10 | BL-18			
105270	1	Lead rope 6kg/m	Lead	36000	
105271	1	Lead rope 6kg/m	Lead	36000	
105498	1	Marine Zipper 108x14m			
105504	1	Marine Zipper 108x14m			
105196	2	MASTERLINK MBL 78t			
104986	26	Ring Chokeline			
105202	2	Rope to secure NF10	Polofine	170000	16 mm
105433	1	RZ Entrance			
105435	1	RZ Extraction Section			
105525	1	RZ Instrumentation			
105443	1	RZ Rope & Bridles AFT			
105436	1	RZ Safe Section			
105343	1	Sea Anchor			
105100	4	SOFT SHACKLE (Double Canus)	Dyneema	500	22mm

Figure 2-2. Retention Zone design.

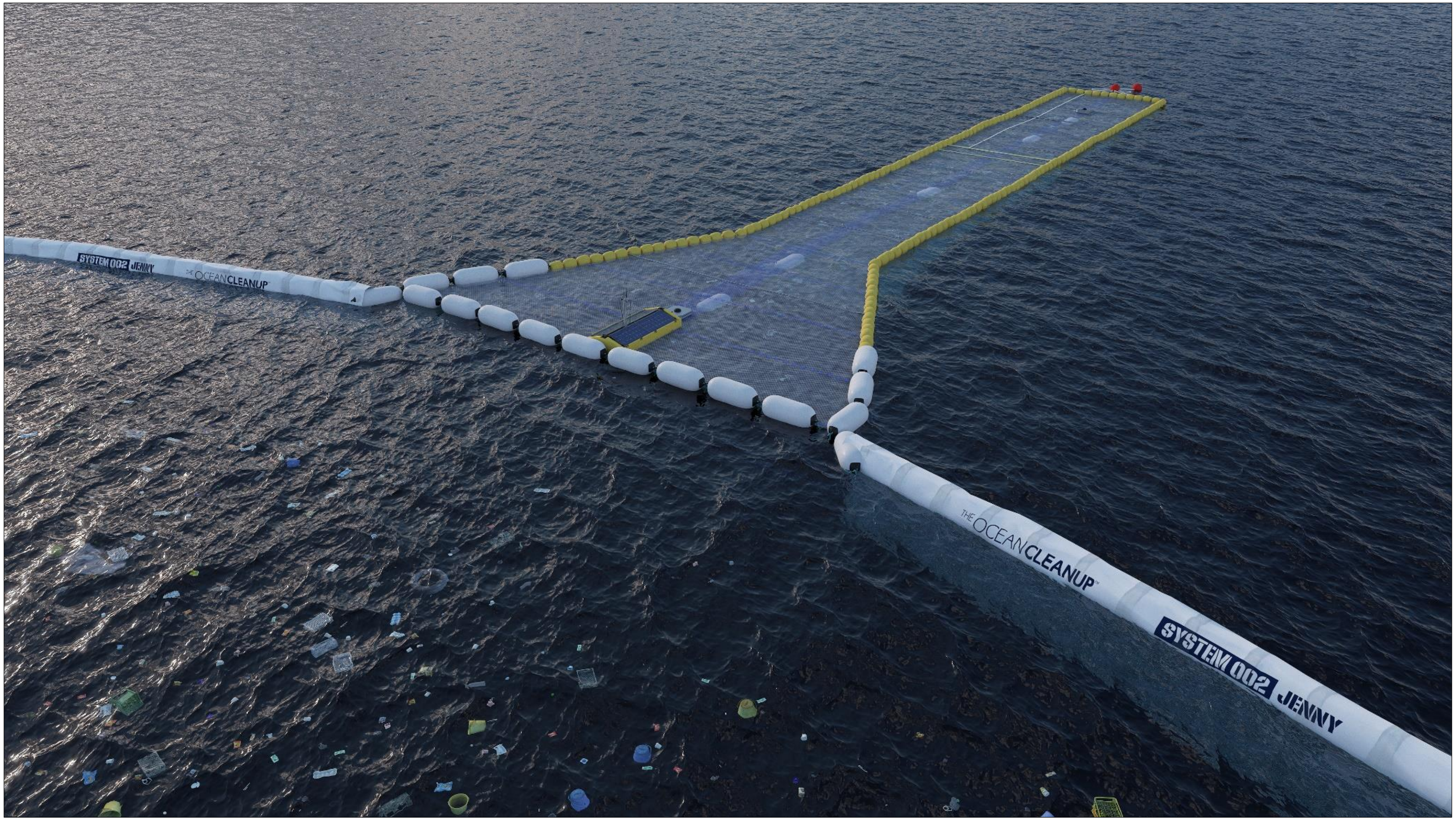


Image 2-2. Retention Zone close-up.

Table 2-1. System wing design parameters.

Defined Parameters	Inputs
Wing length	391 m/wing
Wing depth	3 m constant
Wing height above water	0.5 m
Wing module length	23 m → 17 modules/wing
Net mesh size	10 mm (square)
Wing top section	Permeable screen

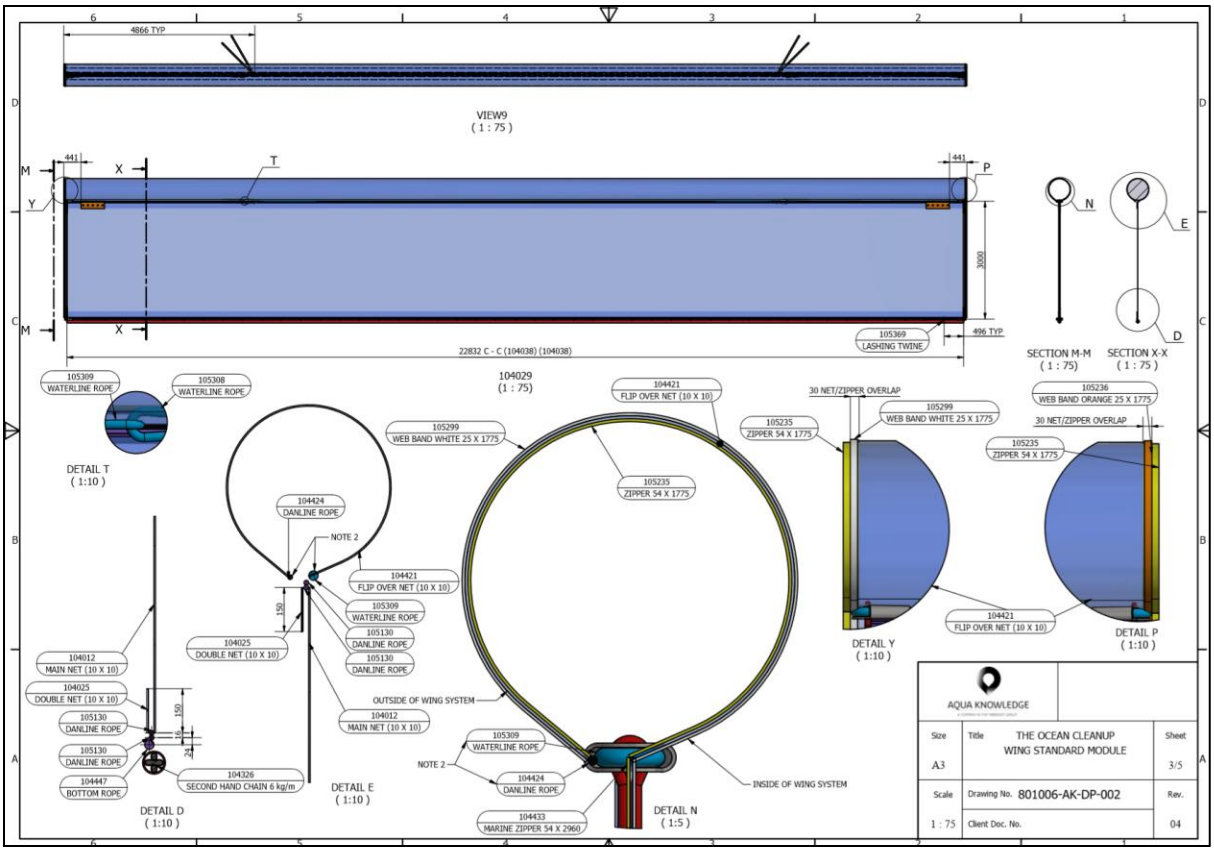


Figure 2-3. Wings and float line design.

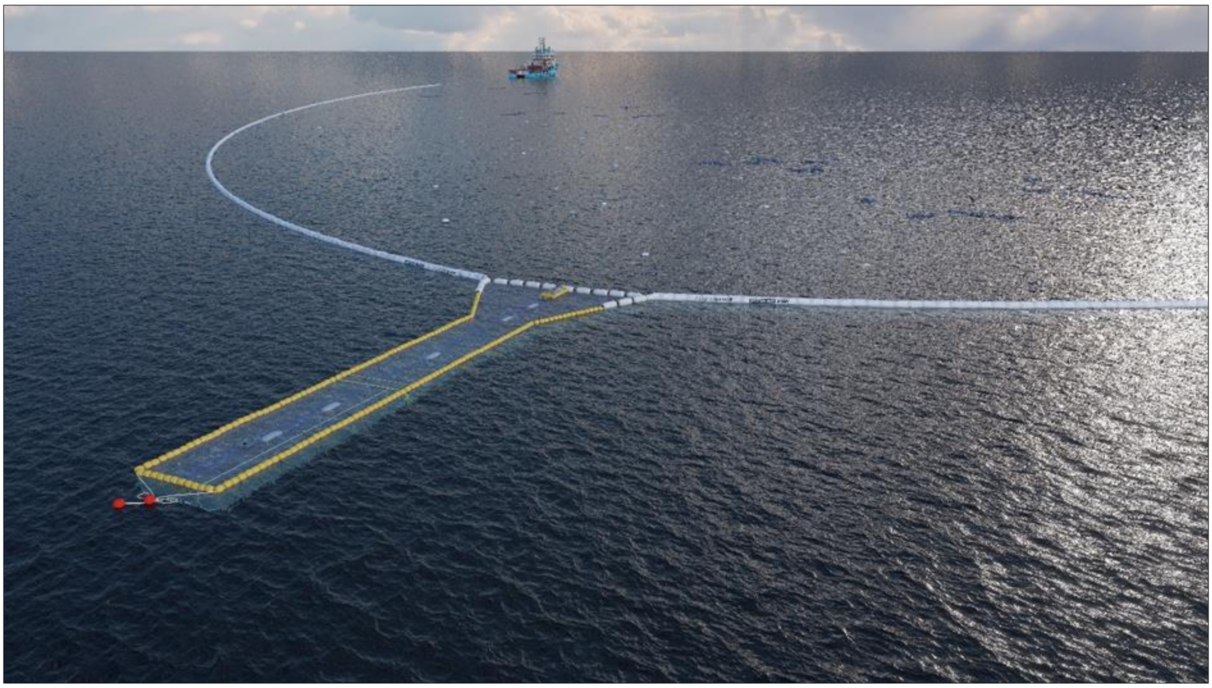


Image 2-3. System 002 in towing configuration.

Located equidistant between the wings (at the back end of the retention system) is a 39-m long, 5-m wide, and from 3 to 2 m-deep RZ where all captured plastics will be collected and retained. The RZ is composed of three different areas: the RZ Entrance, the Safe Section, and the Extraction Section (**Figure 2-4**). The top and sides of the RZ entrance are made of a single layer of 10 mm × 10 mm Square Dyneema® netting (white color). Whereas the RZ entrance bottom will be made of a darker and bigger mesh, 600ply, 123mm INV HM Eurocross 100 × 110# HDPE netting, which has been chosen to theoretically favor downwards escape of smaller fish which otherwise would remain entrapped in the RZ smaller mesh (**Image 2-4**). The other two sections of the RZ are made of a double layer of netting, the inner layer is a 5.0 mm by 5.0 mm Square Dyneema® netting surrounded by an outer layer 300ply, 100mm+ Eurocross 254 ML × 102 HDPE netting. To prevent plastic debris overtopping the RZ, the height is 0.5 m above the water at the RZ entrance and 0.2 m along the RZ length. In three locations (1 for each part of the RZ) along the center line the netting is raised 0.5 m from the water by using 1.5 m × 0.5 m heavy duty floaters. This feature has been added to the design to allow marine life to breathe in case of accidental entrapment. The Safe Section entails an additional mitigation feature, as soon as the bottom of the RZ entrance terminates, a “Fyke opening” is present. This opening 0.4 m deep and 5 m wide has no netting at the front, allowing possible escape by bigger animals. The RZ Entrance and Safe Section have a minimum length necessary to prevent plastic from exiting the RZ in the case of no speed or during an extraction operation; the length is 25 m. The Extraction Section is 103.3 m^3 in volume and approximately 14 m long and 5 m wide for a 2-m deep RZ (**Figure 2-5**).

The Extraction Section is designed to allow for extraction of plastics every 1.2 to 2 weeks and can support a weight of 12.4 T of plastics (dry). If necessary, the Extraction Section length can be increased by the addition of 1 unit of 8 m each (so called Extraction net extension) that can increase by 8 m the RZ total length (max 48 m) and increase the max collectable volume (183 m^3). These two extensions have been considered in case more plastic than expected is collected or to allow for longer deployments.

The RZ design allows for easy and rapid extraction of plastics onboard a T-class vessel. The RZ modules are made to be easily assembled onboard the vessel.

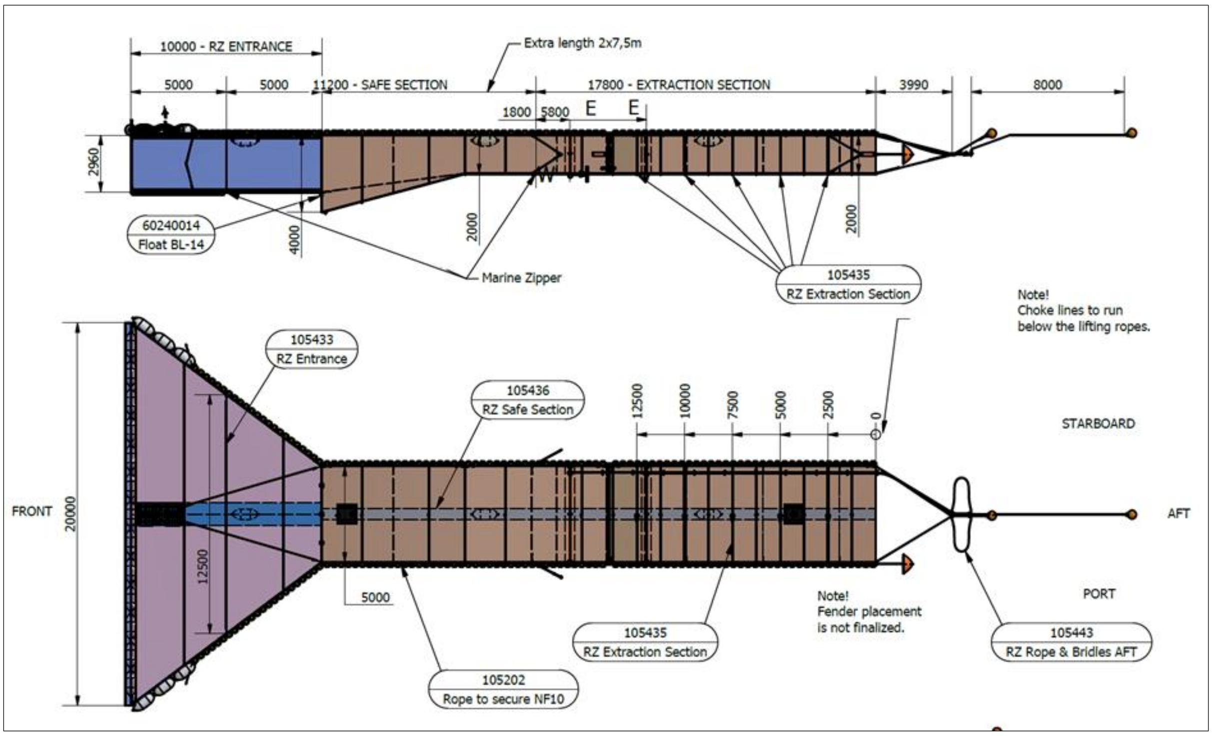


Figure 2-4. Details of the three areas of Retention Zone of S002.

Image 2-4. Top: Retention System netting (10 × 10 mm); Bottom: Retention Zone entrance bottom netting with increased mesh size (50 × 50 mm).

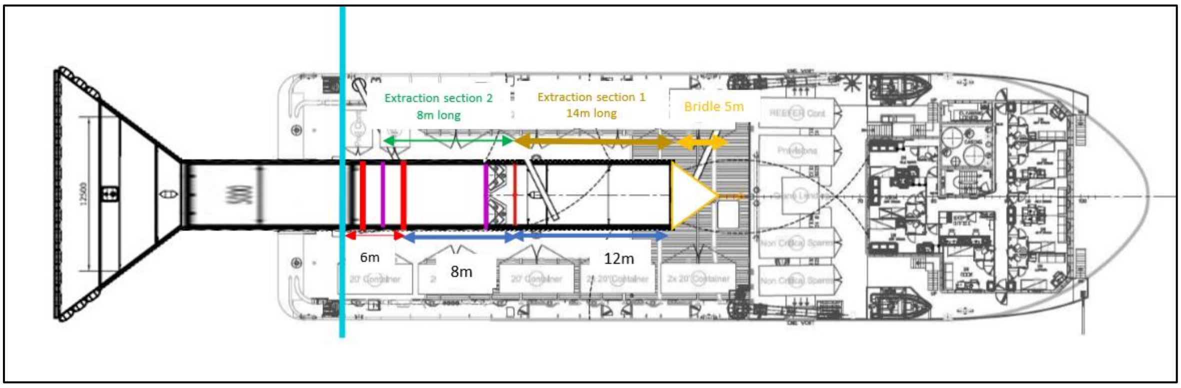


Figure 2-5. Schematic of Retention Zone Extraction Section on vessel deck.

A self-floating unit called Camera Skiff (**Figure 2-6**), developed specifically for S002 project by Seiche Ltd., is mounted on top of the RZ Entrance. This unit is solar powered (4 × 100 W Solar Panels), includes a battery pack (4 × 90Ah Lithium Ion), has an integrated power management system and is connected via WiFi to the vessel's monitoring station. In addition, it has an AIS AtoN transceiver and Echomax active radar reflector, plus a navigational light. This unit allows powering and live streaming visualization of the footage of the two above-water cameras mounted on the Camera Skiff unit itself (1 forward and 1 backward facing) and the three underwater cameras mounted inside the RZ (1 forward and 2 backward facing; **Figure 2-7**). For each underwater camera, a LED light is also present; these lights are dimmable and can be operated directly by a human operator from the control base station on the vessel. The Camera Skiff system has been developed to allow constant monitoring from the vessel bridge of the outside and inside of the RZ, also during night-time and in low visibility conditions, with special focus on the marine life escape aids at the RZ Entrance and safe areas as well as the areas where accumulation of plastic, and possibly marine life, is expected.

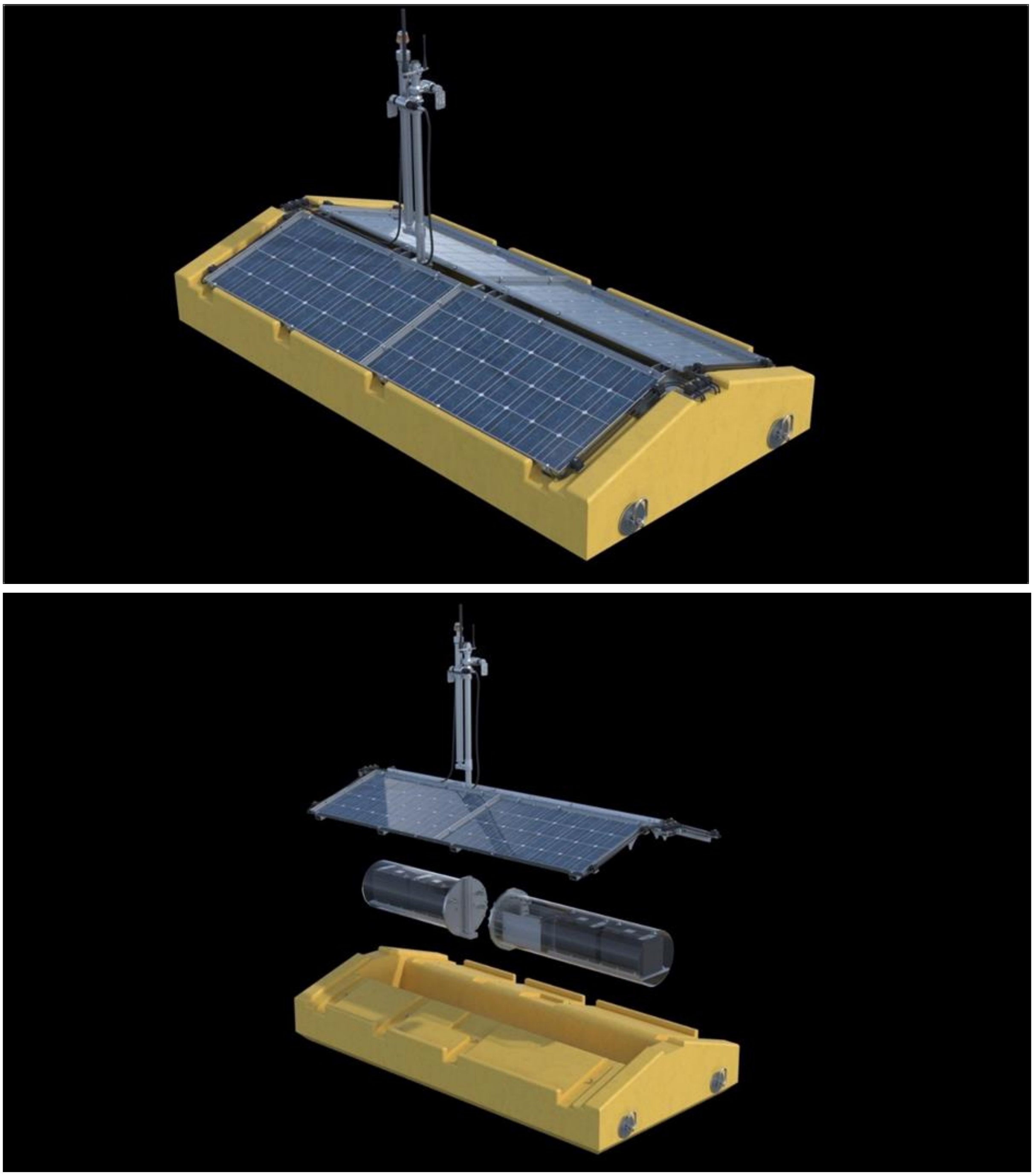


Figure 2-6. Camera skiff unit.

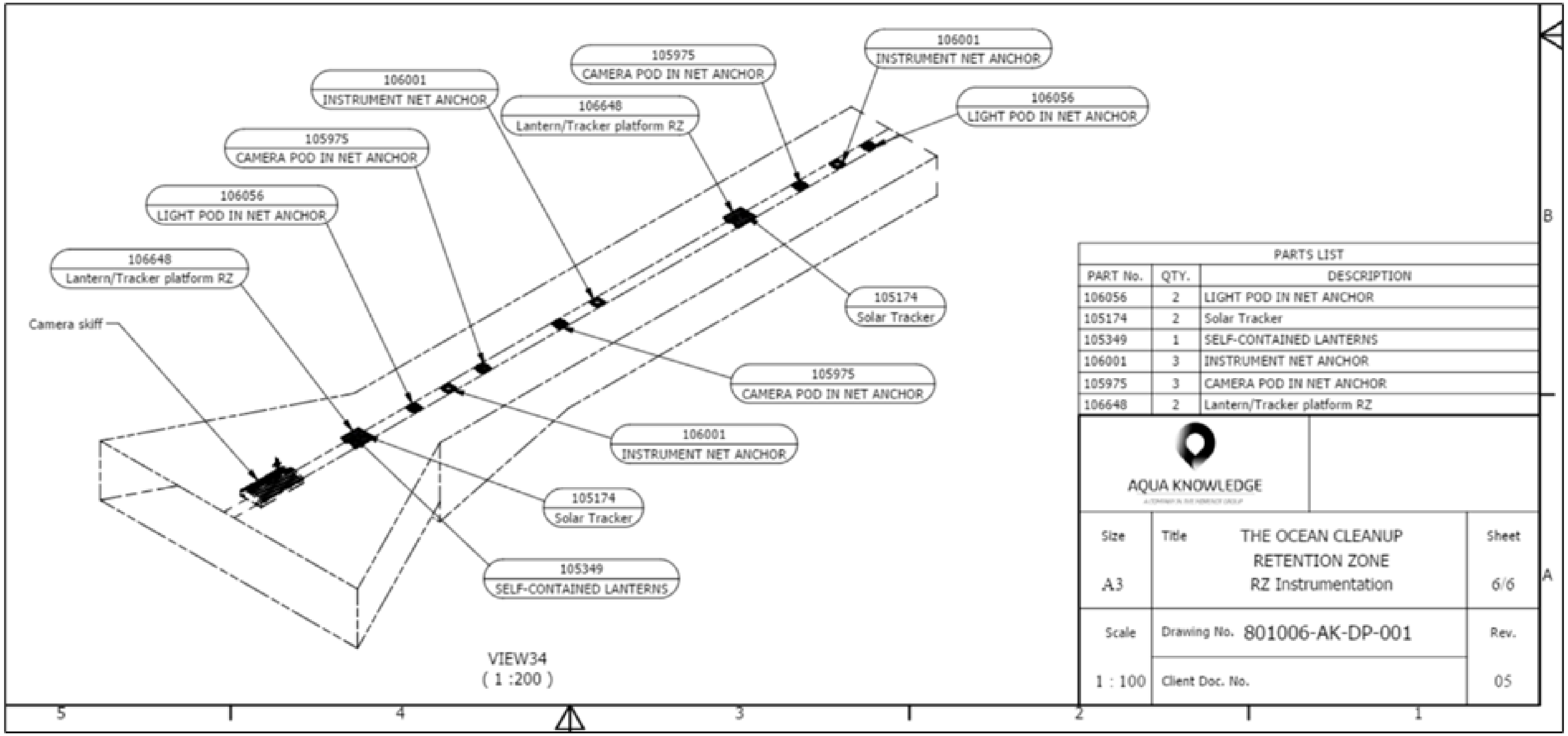


Figure 2-7. Retention Zone Instrumentation.

The RZ includes another mission specific designed mitigation measure, a remotely triggered acoustic quick release for the back end of the of the Extraction section (**Figure 2-8**). With activation of this device, a weight will be released in the water, pulling the line that keeps the end of the RZ Extraction section closed, which once unleashed and fully open, will allow the water flow to flush all the content of the RZ back in the open water. The acoustic quick release will be activated to mitigate the consequences of an unlikely, yet possible, event of a protected species accidentally captured during S002 operation or in case visual observation and camera monitoring should confirm concrete risk or high levels of marine life bycatch. Although the activation of the quick release was tested and confirmed at the production facility, it was not possible to perform a full-scale test with the S002 deployed. Therefore, operational plan includes a series of tests, that will be performed at the beginning of the campaign, to identify the quick release activation limits and requirement as well as the correct offshore procedures such to guarantee the 100% applicability of this mitigation measure.

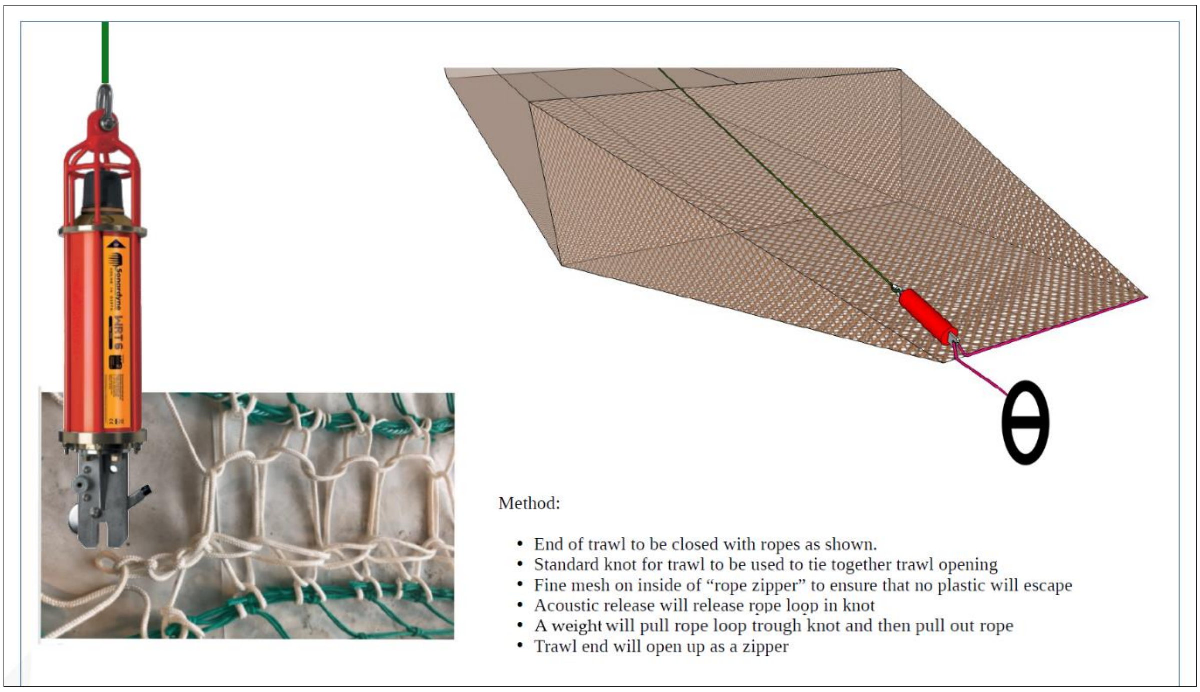


Figure 2-8. Acoustic quick release.

2.1.2 North Sea Test

A small version, similar in design to S002, underwent testing in the North Sea in the last months of 2020. The major issue encountered was the presence of small fish bycatch in the system screen; small amounts of fish bycatch were also present in the RZ after the initial tests. Single instances of fish bycatch were observed on two separate occasions on the wings netting.

Bycatch composition was not very diverse, and in general, small-size fish were found dead in various amounts and conditions. Research will be conducted to assess North Pacific Test bycatch composition and amount in relation to towing speed and accounting for daily and seasonal variations and other possible environmental and project variables.

2.1.3 Plastic Collection Operations

The *Maersk Tender* and the *Maersk Trader* will travel from the Victoria - Vancouver Island area to the deployment location within the NPSG for this North Pacific Test. When the vessels arrive on location, the system modules will be assembled on deck, deployed, and system towing operations will begin. The operations will be supported by 2 smaller workboat for a variety of tasks including monitoring activities (e.g., plankton and bongo net and manta trawl sampling) and other project supporting tasks. Initially, plastics will be extracted from the RZ according to the schedule reported below (**Section 2.1.4**) and later on in the following campaign at less frequent intervals.

Prior to the commencement of plastic collection operations, the area will be inspected for potential presence of marine mammals or sea turtles and other protected species. Observations will be performed visually by Protected Species Observers (PSOs). Extraction operations will not commence unless the area is free of marine mammals and sea turtles and sharks. As soon as the area has been declared clear for protected animals, the S002 will be assembled, and once fully deployed, testing operations will commence. At select times and only in case of necessity during the plastic collection operations, an Acoustic Deterrent Device (ADD) may be deployed to temporarily keep marine life out of the project area.

Table 2-2 provides the schedule for the first 6-week campaign of the North Pacific Test. Transit time to and from the site is not included in the campaign schedule but is anticipated to take between 4 to 6 days each way, depending on the chosen deployment location. Most of plastic transport testing, evaluation of optimal speed through the water and other project related parameters will be performed in the first campaign. Overall, at least 6 analyses of the collected material and RZ density evaluations will be performed in the first 6-week campaign performing the RZ extraction. The other 6-week campaigns are more focused on understanding behavior and performance of the system during long deployment; and therefore, the schedule shown in **Table 2-2** will be modified and include fewer extractions (from 2 to 3).

Table 2-2. S002 6-week (42 day) campaign activities by day for the first campaign. The table does not consider the round transit days from and to Victoria – Vancouver Island (total estimated in max 12 days).

Day(s) of Campaign	Activities Completed
1	Deploy the system during day shift, hold system streaming behind one vessel during night shift
2	Complete deployment of system and tow with one vessel while performing system checks. Connect to second tow vessel at end of day shift
3	Conduct day and night environmental checks, nominal speed tow testing (0.5 knots), perform Bongo/Plankton/Manta net sampling, recover RZ and check contents, re-deploy RZ and continue towing. Night shift tow with nominal span at nominal speed, perform Bongo net sampling.
4	Complete environmental checks and evaluation of test operations and plastic collection
5	Define Optimal Towing Speed #1, and perform Bongo/Plankton net sampling
6	Define Optimal Towing Speed #1 – continue, and perform Bongo/Plankton net sampling
7	Extract RZ, evaluated contents, complete environmental checks to evaluate proceeding with Test Plan, and re-deploy system
8	Define Optimal Towing Speed #2 and perform Bongo/Plankton net sampling
9	Define Optimal Towing Speed #2 – continue and perform Bongo/Plankton net sampling
10	Extract RZ, evaluate contents, complete environmental checks to evaluate proceeding with Test Plan, and redeploy system
11	Define Optimal Towing Speed #3 and perform Bongo/Plankton net sampling
12	Define Optimal Towing Speed #3 – continue and perform Bongo/Plankton net sampling
13	Extract RZ evaluate contents, complete environmental checks to evaluate proceeding with Test Plan, and redeploy system
14	Complete System extraction and Inspection of the RS
15-16	Deploy RS
17-21	First long run test in different configurations: span, STW, heading; perform Bongo/Plankton net sampling

Table 2-2. (Continued).

Day(s) of Campaign	Activities Completed
22-23	Extract RZ, complete environmental checks to evaluate proceeding with Test Plan, and redeploy system
24-29	Second long run test in different configurations: span, STW, heading; perform Bongo/Plankton net sampling
29-30	Extract RZ, complete environmental checks, recover the system, secure system and begin transit to port

RZ = retention zone; RS = retention system, STW = speed through water.

During the North Pacific Test, multiple operational speeds and System configurations will be implemented to collect data regarding the operations and performance of the System as well as documenting bycatch composition and quantity and understanding the environmental mitigation and monitoring measures performance. Tow speeds between 0.5 and 2.5 knots will be tested as well as different span widths of the wings to gather data regarding the efficiency of plastic collection, vessel fuel consumption, environmental factors from the operations, and other operational data. In addition, observations by PSOs and crew, implementation of monitoring and mitigation measures (e.g., above and underwater RZ camera systems, PSOs, thermal/RGB camera system, marine life escape routes, deterrent device), and environmental research (e.g., Bongo/Plankton net sampling, CTD data, manta trawl sampling) will be performed and evaluated to monitoring the environmental impacts of the operations. Data will be collected also for future System testing and design as The Ocean Cleanup intention is to determine the best way forward for System design and operational approach in relation to a potential scaleup scenario and to minimize environmental impacts.

In addition, research will be conducted to assess S002 bycatch composition and amount in relation to different system operational configuration and accounting for daily and seasonal variations and other possible variables. This data will be extrapolated to assess the ecological significance and impact of the bycatch in case of mission continuation and a scaleup scenario. The Ocean Cleanup will also assess the health and safety related to bycatch accumulation in the retention zone.

The deployment location will be based on an expected area of highest plastic density. The Senior Offshore Representative supported by The Ocean Cleanup's engineering and environmental research teams will evaluate all available data and make a recommendation very close to the deployment date. Additionally, the North Pacific Test of S002 may move to different areas of the NPSG throughout the campaign to try and follow the high-and low-density areas, which are shifting, to better understand the system performance in different scenarios. The best estimate for the trial location is currently a generic position in the 'center' of the northern pacific (e.g., Lat. 35°00'.0 N, Long. 145°00'.0 W).

2.1.4 Plastics Extraction Operations

Prior to beginning plastics extraction operations from the Extraction Section of the RZ, the area will be scanned for protected species and other marine life (marine mammals, sea turtles, large fish and sharks) with both PSOs looking at the project area and the footage from the underwater camera system mounted on the RZ to visually monitor the entrance and inside of the retention zone. As soon as the area is cleared of marine mammals, sea turtles, and sharks, the extraction operations will begin, and the towing operations will transfer from two vessels to one vessel reducing the wingspan of the System to approximately 5 m (**Figure 2-9**). The second vessel will then proceed to the RZ end of the system and will retrieve the buoy attached to the RZ bridle and engage two chokes in the RZ to contain the plastics in the Extraction Section. The second vessel will then recover the RZ over the open stern and onto the main deck and secure the System (**Figure 2-10**). After the RZ Extraction Section is detached and secured on deck, the remainder of the S002 (shortened System) will be returned to the water and towed by the single vessel slowly (0.5 to 2.5 knots) while the plastic extraction from the extraction zone is performed by deck crew. This operation is anticipated to take a maximum of 12 hrs. This shortened System has the same design as the complete S002 including all mitigation measures (e.g., “Fyke opening”, camera systems, deterrent lights) with the exception of the acoustic triggered quick release for the choked down shortened RZ. For this reason, the crew on board will try to fully empty the RZ (before and after the yellow choke), so that the shortened RZ can be deployed fully open in the water. Only in the unlikely scenario that plastic cannot be recovered from inside the RZ area, the shortened RZ will be re-deployed still choked and additional monitoring effort will be considered by the onboard PSO, especially for the 3 remaining underwater cameras in the RZ.

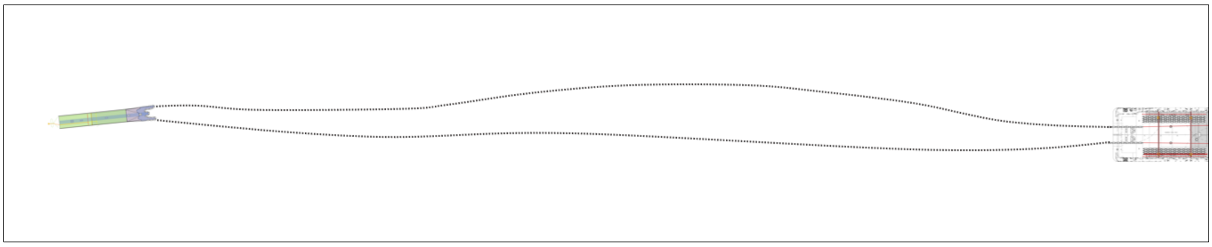


Figure 2-9. S002 during extraction operations behind one vessel with reduced wingspan.

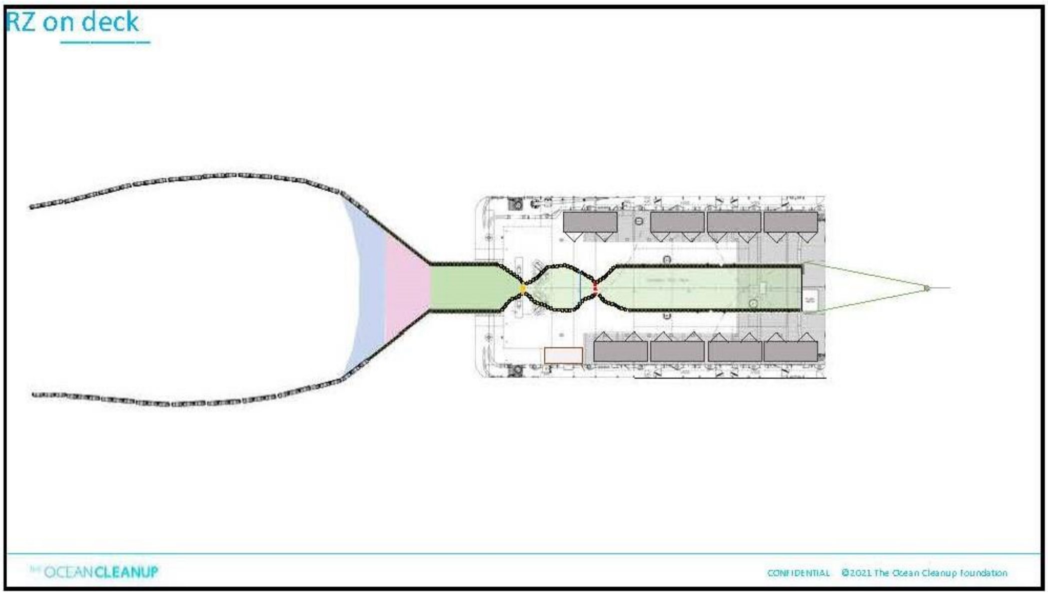


Figure 2-10. Retention Zone with the 2 chokes (Red and Yellow lines) on vessel deck.

Once the plastic is extracted from the Extraction Section and transferred to the vessel storage units, the shortened system will be retrieved by the attached buoy and recovered onboard the vessel to re-attach the RZ Extraction Section. Once the RZ Extraction Section is re-attached, the entire system will be re-deployed and normal plastics collection operations will resume.

After the plastic is transferred to the vessel, living organisms (fish and other marine life) will be manually separated to the extent possible, properly documented, and released back into the ocean (where feasible). This will be done, in part, to understand the amount and type of bycatch in relation to the specific operation just performed, but also to assist in identifying additional mitigation measures for future system improvement. If a living marine mammal or sea turtle or other protected species is unexpectedly found entangled in a derelict net or other debris, a disentanglement and rescue procedure may be initiated considering human safety, weather conditions and the species involved (specific recommendation will be provided in the EMP). Any marine mammal and sea turtle carcasses that may have been trapped in derelict netting will be reported to the Pacific Region of the Canadian Wildlife Service and the appropriate agency in The Netherlands.

Onboard, the plastics will be roughly separated; the ghost nets will be separated from other hard materials. Water shall be allowed to drip off the plastic, which will then be allowed to partially dry during sorting and while it's inspected for biofouling or any other marine life presence. If there is any excessive biofouling, it will be removed. The plastics will be packed onboard the vessel and weighed before being loaded into containers according to the chain of custody guidelines.

The containers will be unloaded in the Victoria area and will remain sealed. Weights will be verified ashore, and the containers will be forwarded to The Ocean Cleanup's partner facility in the Netherlands. After packaging onboard, materials will be in the custody of The Ocean Cleanup Valorization project. Feasible options for further processing of the plastics are underway.

2.2 LOCATION AND SCHEDULE

2.2.1 Location

The mobilization point for the S002 will be the Vancouver, British Columbia, Canada area, from Victoria Harbor, Ogden point cruise terminal.

2.2.2 North Pacific Test Schedule

The proposed activities and testing of S002 is anticipated to depart Victoria, BC area on 27 July 2021 for the first of two 6-week campaigns. After the initial 6-week campaign, the vessel will return to the Victoria Harbour - Vancouver area to change out crew, make any necessary modifications or repairs to the system and head back out for an additional 6-week campaign. There will be a crew changeout on each vessel anticipated at the intermediate port call (6 weeks after departure). The port call is anticipated to be 1 to 2 days.

During operations, there is a possibility to extend the trial to continue to further collect plastic, but if there are issues encountered with system performance (from either operational or environmental perspectives), the trial extension might be put on hold. The extensions could include an additional 6 weeks, or two times 6 weeks, to the already planned two 6-week campaigns.

2.3 PROJECT VESSELS AND EQUIPMENT

The S002 will be transported to the NPSG onboard the *Maersk Tender* or *Maersk Trader*. The vessels are equipped with VHF Radio with digital selective calling, single side band radio, Global Maritime Distress and Safety System, Iridium Satellite phone, NavTex, radar with aft station display, Chart Navigation Computer, GPS, depth sounder, automatic identification system, magnetic compass, autopilot, and dynamic positioning system gyro compasses.

In addition, two workboat will support operations. The workboat is an offshore support vessel for offshore installations and is a deep V-bottom aluminum hulled vessel that will be secured onboard a Maersk vessel for transit and when not in use.

As aid to support Marine Mammals visual observation, The Ocean Cleanup has considered the utilization of a Camera Monitoring System which could help in detecting the presence of marine mammals within the vicinity of the operation. A Camera Monitoring System will be installed on one of the vessels, which comprises 2 × Dual Camera System (High Definition RGB + Thermal) able to scan 24/7 ahead and astern of the vessel in an arc of approximately 200° to 240°. The vessel will be also equipped with a based monitoring station (PC + Monitors), mounted on the bridge.

2.4 EMISSIONS AND DISCHARGES

2.4.1 Emissions

Activities from the proposed North Pacific Test will produce emissions from internal combustion engines, including greenhouse gases, and varying amounts of other pollutants such as carbon monoxide, oxides of nitrogen, and sulfur, volatile organic compounds, and particulate matter. The geographic location of operations ranges from the Victoria, BC area to the proposed deployment location. The amount of air pollutants and greenhouse gases generated during The Ocean Cleanup activities will depend primarily on the number, design, and size of the vessels; the size of engines and generators on the vessels; the distance traversed under power; and overall duration of the activities. An estimated 15 metric tonnes (mt) of fuel will be consumed per day when sailing (transport and return) and 10 mt per day when operating in the NPSG (values are per vessel).

During transport from the port in the Victoria area to the NPSG and back, excluding the transport of material and people to the harbour and excluding mobilisation, 180 mt of emissions are expected based on two vessels sailing for 6 days (15 mt day^{-1}per vessel). During the testing phase, 600 mt of emissions are expected based on the use of two vessels for 30 days of operation (10 mt day^{-1} per vessel). During the return transit (from NPSG to harbor, excluding transport of material and people to the harbour, excl. mobilisation), 180 mt of emissions are expected for two vessels sailing for 6 days (15 mt day^{-1}per vessel). For the two 6 weeks campaign the total fuel consumption expected is therefore 2 times 960mt.

It is The Ocean Cleanup's intention to compensate/offset all CO_2 emissions produced for the project execution and by the vessels' operation by the end of 2021.

2.4.2 Discharges

Discharges from project vessels may include sanitary and domestic wastes, deck drainage, cooling water, bilge water, and food wastes. All sanitary waste will be treated using a marine sanitation device, producing an effluent with low residual chlorine concentrations (i.e., 1.0 mg/L or less), with no visible floating solids or oil and grease. Treated black water discharges will comply with International Convention for the Prevention of Pollution from Ships (MARPOL) requirements.

Domestic waste (also known as gray water) consists of the water generated from showers, sinks, laundries, and galleys, safety showers, and eye wash stations. Domestic wastewater is typically screened to remove any floating solids then discharged; domestic waste does not require treatment before discharge under MARPOL requirements.

Table 2-3 provides a summary of effluent discharges expected during the proposed project and **Table 2-4** provides estimated maximum volumes/weights for sanitary waste, domestic waste, and food waste expected to be generated during the proposed project.

Table 2-3. Summary of effluent discharges expected during The Ocean Cleanup proposed Pacific Trial in the North Pacific Subtropical Gyre.

Effluent	Expected Volumes; Treatment or Processing
Sanitary and Domestic Wastes	Sanitary wastes: 132.5 L/person/d (35 gal/person/d) – macerate, chlorinate, discharge. Domestic wastes: 378.5 to 567.8 L/person/d (100 to 150 gal/person/d) – remove floating solids, discharge. Sanitary wastes will be collected and treated, and domestic wastes will be collected prior to discharge in compliance with MARPOL 73/78, Annex IV. Total volumes of sanitary and domestic waste dependent upon number of personnel.

Table 2-3. (Continued).

Effluent	Expected Volumes; Treatment or Processing
Deck Drainage	Deck drainage to be monitored and treated to remove oil and grease; discharge not to exceed 29 mg/L monthly average, or 42 mg/L daily maximum for hydrocarbons. All discharges will be in compliance with MARPOL 73/78, Annex I. Total volume depends on rainfall.
Cooling Water	Effluent should result in a temperature increase of no more than 3°C (5.4°F) at edge of the zone where initial mixing and dilution take place. Where the dilution zone is not defined, the dilution zone will be 100 m (328 ft) from point of discharge.
Bilge Water	Processed through an oil-water separator. Discharged in compliance with MARPOL 73/78, Annex I. Variable volumes, depending on vessels used.
Food Wastes	Food waste will be ground and passed through 25-mm (1-in) mesh screen prior to disposal overboard outside 22-km (12-nmi) zone as required by the MARPOL Convention (i.e., compliance with MARPOL 73/78, Annex V). Total weight dependent upon number of personnel.

d = day; ft = feet; gal = gallon(s); in = inches; km = kilometers; L = liter(s); MARPOL = International Convention for the Prevention of Pollution from Ships; mg/L = milligram(s) per liter; mm = millimeter(s); nmi = nautical miles(s); ppm = part(s) per million. Generation rates: Per BOEM (2012), a typical offshore facility will discharge 132.5 L (35 gallons) per person per day of treated sanitary wastes and 378.5 to 567.8 L (50-100 gallons) per person per day of domestic wastes, based on U.S. Environmental Protection Agency (USEPA, 1993) estimates. These estimates are considered conservative for sanitary and domestic waste discharges from oil and gas industry support operations, including seismic, guard, and supply vessels.

Table 2-4. Summary of estimated project discharges, reflecting maximum volumes/weights for sanitary waste, domestic waste, and food waste.

Vessels	Duration	Persons (max)	Days (max)	Sanitary Waste (L)	Domestic Waste (L)	Food Waste (kg)
Maersk Tender	Base Campaign (12 Weeks)	22	42[1]	122,430	349,734	924
Maersk Trader		22	42[1]	122,430	349,734	924
			Total (12 Weeks)	**244,860**	**699,468**	**1,848**
Maersk Tender	Extended Campaign (24 Weeks Total)	22	42[1]	122,430	349,734	924
Maersk Trader		22	42[1]	122,430	349,734	924
			Total (24 Weeks)	**489,720**	**1,398,936**	**3,696**

[1] Based on transit of 6 days each way.
kg = kilograms; L = liters.
Generation rates: Per BOEM (2012), a typical offshore facility will discharge 132.5 L (35 gallons) per person per day of treated sanitary wastes and 378.5 to 567.8 L (50-100 gallons) per person per day of domestic wastes, based on U.S. Environmental Protection Agency (USEPA, 1993) estimates. These estimates are considered conservative for sanitary and domestic waste discharges from offshore support operations. Estimated metric rates include: Sanitary waste (black water): 132.5 L/person/day (35 gallons/person/day); Domestic waste (gray water): 378.5 L/person/day (50 gallons/person/day); and Food waste: 1 kg/person/day (2.2 pounds/person/day).

2.4.3 Waste

Waste will be managed in accordance with the vessels' Garbage Management Plans and associated Bridging documentation/contractual conditions with The Ocean Cleanup, as well as all applicable laws and regulations. The Ocean Cleanup will review the Garbage Management Plan and will conduct due diligence on any waste disposal subcontractors that may be hired for the project.

3.0 Legislative and Regulatory Environment

The Ocean Cleanup has its statutory seat in The Netherlands and its activities are subject to Dutch law. States have a duty of care in relation to all operations, activities and processes that are conducted under their jurisdiction or control outside those areas where they exercise sovereign rights under the terms of various international conventions (for example on the basis of Article 194, paragraph 2 of UNCLOS). The Netherlands; therefore, has an obligation to ensure that the activities undertaken by The Ocean Cleanup are in accordance with international standards in order to guarantee that the marine environment, maritime safety, and the rights of other users of the high seas are not put in jeopardy.

For this reason, and in view of the uniqueness of The Ocean Cleanup's system, the Dutch State and The Ocean Cleanup concluded the 2018 "Agreement between the State of the Netherlands and The Ocean Cleanup concerning the deployment of systems designed to clean up plastic floating in the upper surface layer of the high seas" (the Agreement). The Agreement follows, to the extent possible, the legislation applicable to ships that are permitted under Dutch law to fly the Dutch flag. The Ocean Cleanup's systems also bear national identification markings, so that its origin and relationship to the Kingdom of the Netherlands are clearly visible (Article 1.5 of the Agreement). Moreover, the Agreement was drawn up by analogy to the general principles applicable to marine scientific research as set out in Part XIII of the UN Convention on the Law of the Sea (UNCLOS). UNCLOS requires that the elaboration and design of the project be such as to guarantee that every system is sufficiently safe, does not endanger shipping, and takes care to protect the marine environment. The Agreement; therefore, includes, among other things, arrangements with regard to maritime safety (Chapter 2), the protection of the marine environment (Chapter 3), other uses of the high seas (Chapter 4).

The Ocean Cleanup intends to mobilize out of the Vancouver area, with deployment of S002 within the NPSG. Under this mobilization and deployment scenario, The Ocean Cleanup will transit through Canadian coastal waters and Canada's EEZ before reaching international waters. All deployment and testing of S002 will occur in the NPSG, which is located on the high seas (see further **Section 3.1** below). Consequently, and complementing Dutch law and the terms of the Agreement, legislative and regulatory requirements include all international norms applicable to The Ocean Cleanup's activities on the high seas, as well as Canadian regulations which are applicable during the system's transit within Canadian maritime territory.

Brief descriptions of some of the main requirements and regulations involved are provided in the following subsections.

3.1 UNITED NATIONS CONVENTION ON THE LAW OF THE SEA AND AREAS BEYOND NATIONAL JURISDICTION (ABNJs)

Areas beyond national jurisdiction (ABNJs) are areas of ocean for which no single nation has sole responsibility for management. They are recognized as providing habitat for a significant marine biodiversity component, including unique species that have evolved to survive the extreme conditions present (e.g., heat, cold, salinity, pressure, darkness). ABNJs hold unique oceanographic and biological features and play a significant role in climate regulation (Premti, 2018).

UNCLOS provides that ABNJs include 1) the water column beyond the EEZ, or beyond the Territorial Sea where no EEZ has been declared, called the "high seas" (Article 86); and 2) the seabed which lies beyond the limits of the continental shelf, established in conformity with Article 76 of UNCLOS, designated as "the Area" (Article 1). The upper portion of the water column within the NPSG is therefore by definition included in the high seas portion of ABNJs. This region is where The Ocean Cleanup will be testing S002.

A comprehensive global framework for the conservation and sustainable use of ABNJs to halt and prevent further degradation from human activities is currently under discussion. Until a new international instrument regulating ABNJs is agreed upon, the most relevant international legal regime governing those portions of the ocean lying outside of any specific States' jurisdiction can be found under UNCLOS. Article 192 of UNCLOS requires signatories to protect and preserve the marine environment; however, there are no specific mechanisms or processes under UNCLOS for conserving marine biodiversity in ABNJs (Warner, 2014).

While existing regulations govern the exploration and exploitation of the seabed in ABNJs (under the auspices of the International Seabed Authority), there are no current regulations addressing such uses of the water column in ABNJs. Notwithstanding the absence of ABNJs regulations pertinent to the water column, there has been recent activity to protect marine biodiversity within ABNJs. The UN General Assembly adopted Resolution 72/249 in December 2017 to convene an intergovernmental conference ("IGC") to develop an international legally binding instrument on ABNJ marine biodiversity. The first three sessions of the IGC took place on 4 to 17 September 2018, 25 March to 5 April 2019, and 19-30 August 2019. A planned fourth IGC meeting, slated for 23 March to 3 April 2020, was postponed and was held virtually on 14 September 2020 to announce the start of virtual intersessional work ahead of the next in-person meeting in 2021 (International Institute for Sustainable Development, 2021). IGC progress to date includes addressing four key ABNJ issues pertaining to ABNJs: 1) marine genetic resources (MGRs), including questions on benefit-sharing; 2) environmental impact assessments (EIAs); 3) area-based management tools (ABMTs), including marine protected areas (MPAs); and 4) capacity building and marine technology transfer.

Most relevant to The Ocean Cleanup and the proposed testing of S002 are the evolving requirements in relation to EIAs. The IGC recognizes the importance of EIAs as important tools for integrating environmental considerations into decision-making. While definitive guidance regarding EIA content remains to be determined, the IGC has acknowledged that protection of ecologically or biologically significant or vulnerable areas is a priority, and that the development of an EIA for planned activities under a States' jurisdiction and control should be undertaken if those planned activities may result in pollution or an adverse change to the marine environment (Premti, 2018). As negotiations are ongoing, the S002 EIA is being prepared in line with the guiding environmental considerations as well as the draft provisions of the prospective treaty governing ABNJs.

3.2 INTERNATIONAL CONVENTIONS PREVENTING POLLUTION FROM SHIPS

The Ocean Cleanup endeavors to comply fully with all international norms regulating discharge from ships and prohibiting maritime pollution. A key legal instrument in this regard is the 1973 International Convention for the Prevention of Pollution from Ships, also known as MARPOL.

MARPOL (1973) was developed by the International Maritime Organization (IMO) in an effort to reduce marine pollution from vessels. In 1978, MARPOL was updated to include five annexes on ocean dumping; the sixth annex, addressing vessel-based air pollution, was promulgated in 1997. By signing MARPOL, countries agree to enforce Annexes I and II (control of ship-based discharges of oil and noxious liquid substances) of the treaty. Annexes III (harmful substances), IV (sewage), V (prevention of pollution by garbage from ships), and VI (prevention of air pollution from ships) are optional. Both The Netherlands and Canada are signatories to all of the optional MARPOL Annexes.

Annex V is of particular importance to the maritime community including shippers, oil platform personnel, fishers, and recreational boaters because it prohibits the disposal of plastic at sea and regulates the disposal of other types of garbage at sea. Pursuant to the main text of MARPOL, unlawful discharge does not include any release for purposes of legitimate scientific research into pollution abatement and control.

Prohibitions on the disposal of waste in the high seas are also found under the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and its 1996 Protocol (London Protocol), the 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention), the 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention), as well as Article 210 of UNCLOS. All of these legal instruments seek to combat the deliberate disposal of waste or harmful substances from a vessel and provide exemptions for purposes other than disposal or non-deliberate disposal of waste.

3.3 APPLICABLE CANADIAN ENVIRONMENTAL NORMS

The primary Canadian laws requiring an assessment of potential environmental impacts associated with major discretionary projects include the Canadian Environmental Protection Act (CEPA), along with the Oceans Act which is Canada's primary marine protection law.

The proposed deployment location in the NPSG is located in international waters, outside the permitting jurisdiction of Canadian agencies. Further, the activities being proposed by The Ocean Cleanup will not utilize Canadian-flagged vessels. Consequently, Canadian permits that might otherwise be required for a project of this nature are not required. Nevertheless, in the interest of transparency, and to assess the proposed activities for potential environmental impacts and identify potential mitigation measures, this EIA was prepared to meet the 1999 International Association for Impact Assessment (IAIA) Principles of Environmental Impact Assessment Best Practices (IAIA, 1999) and current guidance (e.g., Brownlie and Treweek, 2018), including consideration of local environmental laws and regulations.

The Ocean Cleanup will comply with relevant regulations when transiting nearshore and within the Canadian EEZ. As required, The Ocean Cleanup will issue a Notice to Mariners specifying anticipated transit dates from the Vancouver area and deployment dates in the NPSG. Brief descriptions of relevant Canadian environmental laws are presented below.

3.3.1 Canada Shipping Act (2001)

The Canada Shipping Act of 2001 (Government of Canada, 2001) is the Canadian law implementing MARPOL (**Section 3.1**) in Canadian waters. Transport Canada is the enforcement agency for MARPOL Annex V within the Canadian EEZ, within 370 km (200 nmi) of the Canadian shore. Regulations primarily related to environmental matters under Government of Canada (2001), applicable to The Ocean Cleanup vessel operations, that are presently in force include the Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals (in force under Canada Shipping Act as of 16 May 2007) and the Ballast Water Control and Management Regulations (in force under Canada Shipping Act as of 8 June 2006) (Bird and Purcell, 2007).

Under MARPOL Annex V, as implemented under the Canada Shipping Act, it is illegal to discard plastic waste off any vessel within the Canadian EEZ, except e.g. as part of scientific research into pollution control and abatement. It is also illegal to dispose of any other garbage (e.g., orange peels, paper plates, glass jars, monofilament fishing line) overboard while navigating in inland waters or within 5 km (3 nmi) of shore. The greater the distance from shore, the fewer restrictions apply to non-plastic garbage. However; in general, dumping plastics overboard in any Canadian waters anywhere is illegal at any time. Garbage must be brought ashore and properly disposed of in a trash can, dumpster, or recycling container. Docks and marinas are required to provide facilities to handle normal amounts of garbage from their paying customers.

3.3.2 Species at Risk Act (2002)

The Species at Risk Act (SARA) was enacted in 2002 (Government of Canada, 2002). The act was designed to prevent wildlife species in Canada from becoming extirpated or extinct, provide a strategy for recovery of species which became extirpated as a result of human activity, and guide the management of species of concern to prevent them from becoming threatened or endangered. The SARA is administered by the Minister of the Environment and Climate Change.

The deployment of S002 will occur in international waters using a non-Canadian-flagged vessel and is not subject to SARA rules and regulations except while completing routine transit operations nearshore and within the Canadian EEZ. When operating within the Canadian EEZ, it is highly unlikely that transit operations will result in the take of any SARA-listed species due to the extremely slow speeds utilized in nearshore shipping lanes.

3.3.3 Fisheries Act (2019)

The Fisheries Act (2019) is a broad act that provides protection for fish and fish habitat, protects biodiversity, guides permitting for development project, and addresses habitat restoration and fish stock, among other guidance. The Fisheries Act was originally promulgated in 1868, with a series of subsequent revisions and updates occurring over the years. On 28 August 2019, provisions of the revised Fisheries Act came into force including new protections for fish and fish habitat in the form of standards, codes of practice, and guidelines for projects near water. The Fisheries Act (2019), which is administered by the Minister of the Environment on behalf of the Minister of Fisheries and Oceans, allows for the promulgation of specific regulations addressing marine mammals (**Section 3.3.4**), aquatic invasive species, province-specific fishing, and numerous others.

The Fisheries Act (2019) contains two key provisions relating to conservation and the protection of fish habitat essential to sustaining both freshwater and marine fish species. The Department of Fisheries and Oceans administers section 35, the key habitat protection provision, prohibiting any project or activity that would cause the harmful alteration, disruption, or destruction of fish habitat. Environment and Climate Change Canada administers section 36, the key pollution prevention provision, prohibiting the deposit of deleterious substances into waters frequented by fish, unless authorized by regulations under the Fisheries Act (2019) or other federal legislation (Government of Canada, 2020a).

The deployment of S002 will occur in international waters using a non-Canadian-flagged vessel and is not subject to Fisheries Act rules and regulations except while completing routine transit operations nearshore and within the Canadian EEZ. When operating within the Canadian EEZ, it is highly unlikely that transit operations will result in any negative impacts to fisheries, fish habitat, or biodiversity due to the routine nature of the transit activities.

3.3.4 Marine Mammal Regulations of the Fisheries Act (2019)

Promulgated under the Fisheries Act (2019), the Marine Mammal Regulations (Government of Canada, 2018) were first enacted in 1993 as a consolidation of various regulations of individual species/taxa and were last amended in 2018. The Marine Mammal Regulations address management and control of fishing of marine mammals in Canada and in Canadian fishing waters, and conservation and management of all marine mammals in Canadian waters. The Marine Mammal Regulations are administered by the Minister of the Environment on behalf of the Minister of Fisheries and Oceans.

The deployment of S002 will occur in international waters using a non-Canadian-flagged vessel and is not subject to the Marine Mammal Regulations except while completing routine transit operations nearshore and within the Canadian EEZ. When operating within the Canadian EEZ, it is highly unlikely that transit operations will result in any negative impacts to marine mammals due to the routine nature of the transit activities (MPANetwork, 2021).

3.3.5 Canadian Environmental Protection Act (1999)

The Canadian Environmental Protection Act (CEPA, 1999) was promulgated in 2000. CEPA (1999) is aimed at preventing pollution and protecting the environment and human health. Notably, CEPA (1999) manages environmental impacts of marine pollution and disposal at sea.

The deployment of S002 will occur in international waters using a non-Canadian-flagged vessel and is not subject to CEPA rules and regulations except while completing routine transit operations nearshore and within the Canadian EEZ. When operating within the Canadian EEZ, it is highly unlikely that transit operations will result in any negative environmental impacts due to the routine nature of the transit activities.

3.3.6 Oceans Act (1996)

The Oceans Act (1996) is Canada's primary marine protection law which first came into force in 1997. Among other provisions, the Act outlined ocean management, Canadian marine protected areas (MPAs), and marine environmental quality standards. The Oceans Act (1996) was updated with amendments in 2019. The Oceans Act (1996) is administered by Fisheries and Oceans Canada.

There are a number of different terms used to describe MPAs in Canadian waters, depending on the legislation used to establish them. These include MPAs established under the Oceans Act, national marine conservation areas (NMCAs), national parks, marine wildlife areas, provincial parks, ecological reserves, conservancies, and various First Nations designations (MPANetwork, BC Northern Shelf, 2021).

The deployment of S002 will occur in international waters using a non-Canadian-flagged vessel and is not subject to Oceans Act rules and regulations except while completing routine transit operations nearshore and within the Canadian EEZ. When operating within the Canadian EEZ, it is highly unlikely that transit operations will result in any negative environmental impacts due to the routine nature of the transit activities. If possible, The Ocean Cleanup will avoid Canadian MPAs and other protected areas during transit from the Vancouver area to the NPSG.

3.3.7 Migratory Birds Convention Act (2005)

The Migratory Birds Convention Act of 1917 (amended 1994 and 2005) is the primary legislation in Canada for the conservation of migratory birds. The Migratory Birds Convention Act (2005) allowed implementation of the Migratory Bird Convention, a treaty signed in 1916 with the United States. Consequently, Canadian authorities passed the Migratory Bird Regulations (**Section 3.3.8**). The Minister of the Environment manages the Migratory Birds Convention Act (2005).

3.3.8 Migratory Birds regulations

Promulgated under the Migratory Birds Convention Act (2005), the Regulations protect species of birds that are included in the Migratory Bird Convention. This Act is similar to the U.S. Migratory Bird Treaty Act, although the list of protected species differs somewhat.

The deployment of S002 will occur in international waters using a non-Canadian-flagged vessel and is not subject to Migratory Bird Regulations except while completing routine transit operations nearshore and within the Canadian EEZ. When operating within the Canadian EEZ, it is highly unlikely that transit operations will result in any negative impacts to migratory birds due to the routine nature of the transit activities.

3.3.9 International Union for Conservation of Nature

The International Union for Conservation of Nature (IUCN) is a membership union composed of both government and civil society organizations. Created in 1948, IUCN has evolved into the world's largest and most diverse environmental network. IUCN is the global authority on the status of the natural world and the measures needed to safeguard it.

The IUCN Red List of Threatened Species (Red List) provides taxonomic, conservation status, and distribution information on plants, fungi, and animals that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of individual species' extinction. The main purpose of the IUCN Red List is to catalogue and highlight those plants and animals that are facing a higher risk of global extinction (i.e., those listed as Critically Endangered, Endangered, and Vulnerable). The Red List is widely recognized as the most comprehensive, objective global approach for evaluating the conservation status of plant and animal species. The introduction in 1994 of a scientifically rigorous approach to determine risks of extinction, applicable to all species, has become a world standard. Far more than a list of species and their status, the IUCN Red List is a powerful tool to inform and catalyze action for biodiversity conservation and policy change (IUCN, 2021).

The IUCN Red List status of many of the resources that may be impacted from the deployment of The Ocean Cleanup system and are included in **Section 4.3**. Although most of the regulatory acts discussed only apply while transiting nearshore and within the Canadian EEZ, the Red List provides an internationally recognized conservation status of these biological resources. The Ocean Cleanup's towing and deployment activities have been designed to minimize impacts to marine species, and the removing plastic from the NPSG, will result in a beneficial impact.

4.0 Description of Existing Environment

4.1 PRELIMINARY SCREENING OF ACTIVITIES AND AFFECTED RESOURCES

A preliminary screening was conducted to identify the resources at risk from the S002 deployment in the NPSG. Screening allows for completion of a focused impact analysis by eliminating (from detailed analysis) resources with little or no potential for adverse or significant impact. This approach focuses the analysis on the resources at greatest impact risk. A matrix was developed to list environmental resources in the area of the transit and deployment and project activities that may impact resources (**Table 4-1**). In this preliminary analysis, the level of impact associated with each interaction was categorized as “potential impact for analysis” (i.e., a measurable impact to a resource is predicted) or “no impact expected” (i.e., no measurable impact to a resource is evident).

Several resources were identified as having no expected impacts from the proposed activities. Rationale for exclusion of these resources from further analysis are detailed in the following subsections.

Table 4-1. Preliminary screening of potential impacts (Leopold matrix).

Resource	Project Activity/ Impact Producing Factor					
	S002 – Entanglement/ Entrapment	S002 – Attraction/ Ingestion of Plastics	Vessel – Physical Presence/ Strikes	Noise and Lights	Loss of Debris	Accidental Small Fuel Spill
Air Quality	--	--	--	--	--	--
Sediment Quality	--	--	--	--	--	--
Water Quality	--	--	--	--	--	--
Fish/Fishery Resources	●	●	--	●	●	●
Plankton	●	●	--	●	--	●
Neuston	●	●	--	●	--	●
Benthic Communities	--	--	--	--	--	--
Marine Mammals	●	●	●	●	●	●
Sea Turtles	●	●	●	●	●	●
Coastal and Oceanic Birds	●	●	●	●	●	●
Protected Areas	--	--	●	--	--	●
Biodiversity	U	U	U	U	U	U
Commercial and Military Vessels	--	--	●	--	--	--
Archaeological Resources	--	--	--	--	--	--
Human Resources, Land Use, and Economics	--	--	--	--	--	--
Recreational Resources and Tourism	--	--	--	--	--	--
Physical Oceanography	--	--	--	--	--	--

● indicates a potential impact; - indicates no impact expected; U indicates that there is not enough information at this time to assess.

4.1.1 Air Quality

Potential impacts from emissions on air quality are expected to be negligible. Vessels (transiting, monitoring, and debris collection), machinery, and equipment involved in The Ocean Cleanup’s activities will emit a variety of air pollutants, including nitrogen oxides, sulfur oxides, particulate matter, volatile organic compounds, and carbon monoxide, as well as greenhouse gases (e.g., carbon dioxide) primarily from combustion of fossil fuels for propulsion and power generation. The amount of air pollutants and greenhouse gases generated during The Ocean Cleanup activities will depend primarily on the number, design, and size of the vessels; the size of engines and generators on the vessels; the distance traversed under power; and overall duration of the activities, however, due to the limited extent and duration of activities, the amount of pollutants is expected to be nominal.

Ambient air quality in the Vancouver area is generally deemed healthy, typically posing little to no risk to human health. While annual air quality averages rank Vancouver among the cleanest major cities in the world, unhealthy short-term pollution spikes are not uncommon. For example, there were 30 incidents of short-term air pollution documented in 2019, based on one or more exceedances, including 1) 24-hr average $PM_{2.5}$ concentration >25 µg m^{-3}; 2) 1-hr average nitrogen dioxide (NO_2) concentration >200 µg m^{-3}; 3) 24-hr average sulfur dioxide (SO_2) concentration >20 µg m^{-3}; and 4) 8-hr ground-level ozone (O_3) concentration >52 parts per billion (ppb) (IQAir, 2021*)*.

Air emissions from The Ocean Cleanup vessels will contribute nominal amounts of pollutants to the emissions inventories attributed to other vessels in the waters offshore of the Vancouver area. Project vessels will also have a very short term and limited impact to ambient air quality in the Vancouver area, primarily due to the short duration of vessel presence while berthed (during mobilization) and during transit while in close proximity to the Vancouver area and Canadian coastline.

Air quality could also be temporarily affected by an accidental fuel spill in the immediate vicinity of vessel operations, but due to the small volume of a potential spill and the high volatility of refined fuels, any impacts on air quality are expected to be negligible (i.e., localized, short term). For these reasons, a more extensive analysis of air quality emissions associated with anticipated operations will not be performed as part of this EIA.

4.1.2 Sediment Quality

There are no activities proposed by The Ocean Cleanup that could have substantial impacts on sediment quality. No anchors or other bottom disturbing activities will occur during the transit or deployment and consequently a more detailed analysis of potential impacts to sediment quality will not be performed as part of this EIA.

4.1.3 Water Quality

Potential impacts from vessel discharges on water quality are expected to be negligible. The project vessels will discharge treated sanitary and domestic wastes in compliance with MARPOL Annex IV along with miscellaneous discharges (e.g., deck drainage, bilge water, machinery space drainage). The volume of treated discharges generated during The Ocean Cleanup activities will depend primarily on the design and size of the vessels, the onboard crew compliment, the distance traversed, and the overall duration of activities. Most discharges will occur outside the Canadian EEZ in international waters and will quickly become diluted in seawater.

Furthermore, all vessels are subject to the regulations of MARPOL 73/78, as modified by the Protocol of 1978 (**Section 3.1**). MARPOL includes six annexes that cover discharge of oil, noxious liquid substances, harmful packaged substances, sewage, garbage, and air pollution (IMO, 2017). Annex V specifically prohibits plastic disposal anywhere at sea and severely restricts discharge of other garbage (IMO, 2017). Adherence to these regulations minimizes or negates the likelihood of discharges of potentially harmful substances into the marine environment.

Water quality could be temporarily affected by an accidental fuel spill in the immediate vicinity of the spill. The extent and persistence of water quality impacts from a small diesel fuel spill would depend on the meteorological and oceanographic conditions at the time and the effectiveness of spill response measures, but diesel fuel rapidly evaporates and is completely degraded for naturally occurring microbes (NOAA, 2006). It is not expected that the impacts to water quality from an accidental fuel spill will be significant. For these reasons, more detailed analysis of water quality impacts associated with anticipated The Ocean Cleanup activities will not be performed as part of this EIA.

4.1.4 Benthic Communities

There are no activities proposed by The Ocean Cleanup that could have substantial impacts on benthic communities. No anchors or other bottom disturbing activities will occur during the transit or deployment, consequently a more detailed analysis of impacts to benthic communities will not be performed as part of this EIA.

4.1.5 Archaeological Resources

No impacts to archaeological resources are anticipated from The Ocean Cleanup activities. No seafloor disturbing activities are proposed that would have the potential to impact shipwrecks or other submerged archaeological resources. Mobilization is expected to occur in the Vancouver area in a developed, industrial area with no known archaeological resources nearby. The Ocean Cleanup project does not involve any new land-based development. Consequently, a more detailed analysis of archaeological resources will not be performed as part of this EIA.

4.1.6 Human Resources, Land Use, and Economics

No substantial impacts to human resources, land use, or economics are expected from The Ocean Cleanup activities. The Ocean Cleanup activities will result in a minor positive economic benefit due to payments to federal, provincial, and/or local authorities and private parties for port fees, fuel, other miscellaneous purchases, potential employment opportunities during mobilization, and other incidental expenses incurred while in the Vancouver area and the surrounding area. No alteration to land use is proposed and no new ports or other infrastructure will be built. Collected plastics will be returned to the Vancouver area in sealed containers before being forwarded on to The Ocean Cleanup's facility in the Netherlands.

4.1.7 Recreational Resources and Tourism

Impacts to recreational resources and tourism from The Ocean Cleanup activities are expected to be negligible. There are no known recreational or tourism resources in the NPSG as it is located in a remote area of open ocean more than 1,800 km (1,000 nmi) from land. Recreational or tourism boating activities may be briefly interrupted during the transit of the project vessels out of the Strait of Georgia and the Strait of Juan de Fuca; The Ocean Cleanup will coordinate with Transit Canada to issue any required NTM to mitigate potential impacts. As a result of the temporary and negligible impacts expected, more detailed analysis of potential impacts to recreation resources and tourism will not be performed as part of this EIA.

4.1.8 Physical Oceanography

Physical oceanographic resources will not be affected by The Ocean Cleanup activities and associated discharges; impacts to physical oceanography are expected to be negligible. Ocean current characteristics, water column density stratification, wave height, directional spectra, and vertical current structure, among other factors, will be considered during planning, deployment, and debris recovery operations.

4.2 DATA SOURCES

Utilizing information provided by The Ocean Cleanup and the CSA Ocean Sciences Inc. (CSA) Research Library facility, CSA conducted a comprehensive review based on literature, previously completed environmental studies, and EIAs concerning projects in the region. Project area-specific information is limited; as such, regional data was utilized to characterize the marine environment in the project area.

4.3 BIOLOGICAL ENVIRONMENT

4.3.1 Plankton

4.3.1.1 Plankton in the North Pacific Subtropical Gyre

The NPSG is a large system of circulating currents covering an area that extends from approximately 15°N to 35°N latitude and 135°E to 135°W longitude. With a surface area of approximately 2×10^7 km^2, the NPGS is the largest circulation feature on the planet (Karl, 1999). The NPSG includes a broad range of habitats that are both temporally and spatially variable (Karl, 1999; Karl and Church, 2017).

Within the NPSG, picoplankton is the dominant group in terms of abundance (more than 50% of the total), while relative abundance of diatoms and dinoflagellates is less than 15% of the total (Uitz et al., 2006, 2010). *Prochlorococcus*, a cyanobacteria, accounts for >75% of the photoautotrophic biomass in the upper portion of the water column (Karl et al., 2001).

Seasonally, zooplankton biomass peaks are observed during the summer months of highest primary productivity. Increased sea surface temperature, stratification, and nitrogen fixation happen during summer, which is reflected in maxima of primary production and zooplankton biomass. Many species of zooplankton undergo diel vertical migration where they move up to the epipelagic zone in the water column at night and return to the mesopelagic zone during the day.

Seasonality in phytoplankton has also been observed. During summer, surface species are found in the upper 75 m (246 ft) whereas deep species found from 75 to 150 m (246 to 492 ft) bloomed in winter (Campbell et al., 1997; Batten and Freeland, 2007). Other studies show low plankton abundance in winter associated with the North Pacific Current (Batten and Freeland, 2007), an eastward-flowing current that splits into the southward-flowing California Current and the northward-flowing Alaska Current within the southeastern Gulf of Alaska.

Studies related to other plankton groups, like diatoms, show low concentrations of diatom cells throughout the year, although distinct assemblages were observed in the mixed-layer and in the deep chlorophyll maximum layer. However, a conspicuous increase in diatom concentration was observed, particularly in the mixed-layer in July, mainly by *Hemiaulus hauckii* and *Mastogloia woodiana* (Scharek et al., 1999).

Summer plankton blooms are a common seasonal phenomenon in the NPSG. A high-frequency area of bloom occurrences in the NPSG is generally centered along 30°N, about 130 to 160°W (Dore et al., 2008). The largest historical blooms have covered more than 350,000 km^2 (102,044 nmi^2) and lasted as long as four months (Wilson, 2003). Blooms occur annually between the months of June and October and are generally observed coincident with sea surface temperatures >25°C (>77°F) and mixed layer depth <70 m (>230 ft). Some blooms are dominated by *Richelia*-diatom symbioses, while others by *Trichodesmium*, a filamentous cyanobacteria (White et al., 2007).

4.3.1.2 Gelatinous Macrozooplankton

Gelatinous macrozooplankton (e.g., jellyfish, ctenophores) belong to the phyla Cnidaria. Little is known about the population abundance or dynamics of most species of jellyfish as many live in open ocean environments. **Table 4-2** lists species that have been found in or nearby the deployment area for S002 in the NPSG.

During The Ocean Cleanup's deployment of System 001B in the NPSG in 2019, an estimated 500 colonies of *Velella velella* were collected in the system as bycatch, indicating their common presence in the NPSG during the collection period. One other species of gelatinous microzooplankton was identified during the 2019 campaign (Violet sea snail; *Janthina janthina*); however, the degraded nature of the shells did not allow for an estimate of the number of colonies.

Table 4-2. Cnidarian species that have been reported in the vicinity of the S002 deployment in the North Pacific Subtropical Gyre. Data from: Wrobel and Mills (1998).

Class	Species	Climate Region or Geographic Range	Dominant Occurrence	Buoyancy (Positive/Neutral)	Feeding
Hydrozoa	*Algantha digitale*	North Pacific Water 40°N to Arctic waters	Arctic water and open ocean	Neutral	At night at surface
	Velella velella	Tropical and temperate waters	Open ocean	Positive	At surface
	Pegantha spp.	40°N to 40°S	Open ocean	Neutral	--
	Liriope tetraphylla	40°N to 40°S	Open ocean and near coast	Neutral	--
	Physalia utriculus	North Pacific and Hawaiian waters	Open ocean	Positive	At surface
	Physophora hydrostatica	Tropical and temperate waters	Deep midwaters	Neutral	Deep waters
	Porpita porpita	Tropical and sub-tropical waters	Open ocean and near coast	Positive	At surface
Scyphozoa	*Aurelia aurita*	70°N to 40°S	Mostly inshore; can be found in open water	Neutral	Water column
	Aurelia labiata	North Pacific from California to Japan	Mostly inshore can be found in open water	Neutral	Water column
	Phacellophora camtschatica	Temperate waters from Gulf of Alaska to Chile	Open ocean	Neutral	Water column

-- = Feeding method unknown.

4.3.1.3 Ichthyoplankton

Data regarding ichthyoplankton in the project area are sparse, but it is likely that many of the pelagic fish species discussed in **Section 4.3.3** may be present in larval form as well. Loeb (1979) described larval fish assemblages in the NPSG. Ichthyoplankton collected from six cruises resulted in approximately 30,000 individual larvae from over 150 species, primarily mesopelagic species. However, it should be noted that Loeb (1979) reported that fish larvae constituted <2% of the total macrozooplankton collected in the NPSG. While overall fish larvae abundance was not found to differ by season, ichthyoplankton species composition did vary by season. Prominent families noted included Myctophidae (lanternfish), Gonostomatidae (bristlemouths), and Sternoptychidae (hatchetfishes), constituting more than 84% of the larval specimens collected in the NPSG.

Ichthyoplankton contributions, by family and for these three predominant families, exhibited similar patterns in the eastern tropical Pacific Ocean, within the California Current offshore area, and in the Indian Ocean (Loeb, 1979).

4.3.1.4 Plankton in the California Current

The California Current is a Pacific Ocean current that flows southward from approximately 50° N latitude (roughly parallel to Vancouver Island) to offshore Baja California, approximately 15° to 25° N latitude. The current is largely driven by atmospheric pressure gradients and winds offshore the west coast of North America (Checkley and Barth, 2009), which are predominantly from the northwest, especially during summer.

The California Current System (CCS) upwelling is generally lowest during the winter and increases to peak levels during the late spring and summer months (Black et al., 2011). From October to March, conditions in the eastern North Pacific, along the western coast of North America, are predominantly downwelling: the water column is well-stratified, the standing stock of primary producers is low, and productivity is generally light or nutrient limited (White et al., 2014).

In the CCS, abrupt changes in zooplankton biomass and community structure on inter-annual scales are strongly linked to fluctuations of El Niño (Valencia et al., 2016). During El Niño a deepening of the nutricline (a zone within which nutrient levels decline rapidly with depth of water) is expected; consequently, primary productivity decreases, as well as macrozooplankton biomass. However, individual taxa responses can vary. For example, the biomass of copepods and euphausiids (krill) underwent only a minor decrease during the El Niño of 1958-1959 (Lavaniegos et al., 2002).

Studies related to zooplankton variations during El Niño/La Niña events show that monthly-averaged copepod species richness was anomalously high throughout most of 1996-1998 and low from winter 1999 to autumn 2002. The proportion of euphausiids was similar during the period analyzed, but the proportions of copepods and salps changed. Copepods were more abundant during the El Niño Southern Oscillation peak, and salps more abundant in the transition phases between peaks (Lavaniegos et al., 2002).

Seasonality in regional coastal phytoplankton offshore California has also been reported, with concentrations of nano- and microphytoplankton lower during the winter and reach their maximum density in the summer (Trujillo et al., 2001). A study shows that the phytoplankton net primary production (NPP) in the CCS has a strong annual periodicity correlated with El Niño/La Niña events. During El Niño events, NPP had been reported to have a 30% reduction at a location 100 to 300 km (54 to 162 nmi) off southern California, meanwhile a 40% increase was observed off Baja California. During its peak, NPP decreased during El Niño by 10 to 15% in the 1,000-km band off Southern California but increased by 20 to 30% off Northern and Southern Baja. The total annual NPP was lowest during the El Niño years of 1997-1998 and peaked in 2000. Trends of increasing NPP and zooplankton volume were observed off Central and Southern California with the onset of La Niña (Kahru and Mitchell, 2002). The current El Niño/La Niña forecast for mid to late 2018, according to NOAA (2018), indicates a 50% chance for El Niño conditions in the fall of 2018 and a 65% chance of El Niño conditions in the winter of 2018.

Shifts in phytoplankton community composition are observed over the upwelling/downwelling seasonal progression. During upwelling events, diatoms numbers increase due to high nutrient levels, whereas dinoflagellate concentrations increase during the nutrient-depleted, stratified summer periods and during the phases that interrupt upwelling events.

Blooms of the dinoflagellate, *Akashiwo sanguinea*, have been reported in the U.S Pacific Northwest, off the California coast. In 2004, a large *A. sanguinea* (also known as *Gymnodinium splendens* or

Gymnodinium sanguineum) bloom was observed in San Francisco Bay and attributed to an upper-atmosphere high-pressure anomaly following a summer of weak coastal upwelling. At some locations, *A. sanguinea* persisted well into November and December of 2009, when sea surface temperature was anomalously warm (White et al., 2014).

4.3.1.5 Plankton in the Straits of Georgia and Juan de Fuca

Plankton communities in the Strait of Georgia and Strait of Juan de Fuca in the Vancouver area are critical habitats for plankton because they serve as important feeding grounds and migration corridors for several of Canada's Pacific salmon stocks and as spawning areas for herring (Costalago et al., 2020).

Historically, plankton in the Strait of Juan de Fuca and surrounding waters have not been well studied. Chester et al. (1980) prepared a report for the U.S. EPA characterizing the composition of phytoplankton, zooplankton, and ichthyoplankton in the Strait of Juan de Fuca. Results indicated that phytoplankton were primarily composed of flagellates during the fall and winter months, with diatoms blooming in the spring and summer. Zooplankton were dominated by copepods, specifically calanoid and cyclopoid taxa. Ichthyoplankton and fish eggs were most common in late winter and early spring. The most common group identified were the osmerids (smelt). Other common taxa included *Ammodytes hexapterus* (Pacific sand lance), *Sebastes* spp. (rockfishes), *Hemilepidotus* spp. (Irish lords), and taxa from the groups Cottidae, Gadidae, and Clycopoteridae (Chester et al., 1980).

More recent studies have confirmed the findings by Chester et al. (1980) that the plankton food web is largely driven by diatoms and flagellates (Costalago et al., 2020). Moreover, Costalago et al. (2020) showed that based on analyzed fatty acid composition of zooplankton (e.g., copepods, decapods, euphausiids), the dominant plankton organisms shift seasonally, with diatoms dominant during the spring bloom, but flagellates dominating during the summer (Costalago et al., 2020). This shift is critical as it supplies more nutritious food for critical fish stocks utilizing the Straits. A recent 4-year study utilizing liquid chromatography to analyze phytoplankton pigments also identified diatoms as the dominant contributor to annual phytoplankton biomass during spring blooms (Del Bel Belluz et al., 2021). In the summer, other significant phytoplankters in the Strait of Georgia included prasinophytes and cryptophytes (Del Bel Belluz et al., 2021).

Springtime larval fish (ichthyoplankton) taxa were characterized during three field surveys in the Strait of Georgia by Guan et al. (2017) over a period from 2007 to 2010. A total of 49 taxa from 23 families were identified. Species dominance varied by year, but the most common taxa identified were *Clupea pallasi* (Pacific herring), *Gadus chalcogrammus* (Alaska pollock), *Merluccius productus* (North Pacific hake), *Leuroglossus schmidti* (Northern smoothtongue), *Lyopsetta exilis* (Slender sole) and *Sebastes* spp. (Guan et al., 2017).

4.3.2 Neuston

The marine neuston community is a specialized subset of the pelagic community associated with the air-sea interface (Marshall and Gladyshev, 2009). A review by Marshall and Burchardt (2005), including determinations and contributions from earlier researchers (e.g., David, 1967; Zaitsev, 1971; Hempel and Weikert, 1972; Banse, 1975), further defined the community that comprises the neuston, as summarized by Goldstein (2012), including definitions based on location in the water column (1-3), as well as life stage (4-6):

1) Epineuston, defined as organisms that live on the water's surface and are exposed to air;
2) Hyponeuston, defined as organisms that live on the underside of the surface layer;
3) Metaneuston or Exopleuston, including those organisms that occupy space both above and below the water (e.g., siphonophore *Physalia physalis*);

4) Euhyponeuston, defined as those organisms that are associated with the surface film for their entire life cycle;
5) Planktohyponeuston, including those organisms that vertically migrate; and
6) Merohyponeuston or Endopleuston, defined as those organisms that inhabit this space for only a portion of their lives.

Some researchers refer to the entire upper water column as the epineuston and have to differentiate the surface-associated portion of the upper water column as the pleustal zone and the biota that live there as the pleuston (Banse, 1975; Cheng, 1975). For the purposes of this characterization, the approach of Goldstein (2012) has been applied, where the neuston encompasses both the surface habitat and its associated biota.

Definition of the depth of the neuston layer also varies, depending upon the source. Hardy (1997) and Champalbert et al. (2003), amongst others, have considered the upper 1 m of the ocean as the sea surface layer, while Zaitsev (1971) and Zaitsev et al. (1997), per Marshall and Burchardt (2005), considered the upper 5 cm of the ocean as the neuston. The physical, chemical, and biological conditions found within the uppermost 5 cm of the water column differ greatly from those found below. For the purposes of this baseline characterization, the neuston layer follows the convention of Zaitsev (1971), occupying the sea surface and the upper 5 cm of the water column.

The following discussion summarizes important data regarding neuston present in the NPSG, including free floating biota (invertebrates, vertebrates) and those taxa found in direct association with floating debris (i.e., the rafting assemblage).

4.3.2.1 Free Floating Neuston

Goldstein (2012) observed that the oceanic neustonic assemblage is distinct from the biota found lower in the water column only within tropical and subtropical waters located between 40° N and 40° S; in this region, sea surface temperature rarely falls below 10°C (Savilov, 1968 as cited in Cheng, 1975). The neuston zooplankton community exhibits a vibrant blue and purple coloration, including cnidarians, pontellid copepods, and gastropods (Goldstein, 2012).

According to Goldstein (2012), the neustonic zooplankton community is dominated by a relatively small number of relatively conspicuous, drifting organisms. Obligate sea surface-associated cnidarians include the siphonophore *Physalia physalis* and the chondrophores *Velella velella* and *Porpita porpita*. *Physalia* is an important prey item for the nudibranchs *Glaucus atlantica* and *Glaucilla* spp. *Velella* and *Porpita* are prey for the prosobranch gastropod *Janthina* spp. (Bieri, 1966). Glaucinin nudibranchs are neustonic predators, and primarily consume the drifting hydrozoan cnidarians *Porpita porpita*, *Velella velella*, and *Physalia physalis* (Lalli and Gilmer, 1989). The gerrid insect *Halobates* spp. and pontellid copepods are also an abundant component of the neuston, per Herring (1967), Cheng (1975), and Goldstein et al. (2012).

Velella velella is a cosmopolitan, holoplanktonic, free-floating marine hydrozoan living in open waters at tropical and temperate latitudes (Pires et al. 2018; Betti et al., 2019). The floating *Velella* hydranth stage are known to frequently form enormous congregations offshore, often comprised of hundreds of thousands of colonial polyps (Purcell et al., 2012). Large occurrences of *Velella* have a significant effect on the planktonic trophic web, with *V. velella* being an active predator of zooplankton, including fish eggs and juveniles (Purcell et al., 2015). In turn, *V. velella* is preyed upon by several pleustonic gastropods belonging to the genus *Janthina* and several different nudibranch taxa (e.g., *Glaucus atlanticus* and *Fiona pinnata*), as well as loggerhead sea turtles (*Caretta caretta*) and the sunfish *Mola mola* (Betti et al., 2017, 2019). Other cnidarians found within the vicinity of the NPSG include *Algantha digitale*, *Liriope tetraphylla*, *Pegantha* spp., *Physalia utriculus*, and *Physophora hydrostatica* (Wrobel and Mills, 1998).

Salps found within the NPSG include *Cyclosalpa pinnata*, *Iasis cylindrica*, *Salpa aspera*, *Cyclosalpa bakeri*, *Salpa fusiformis*, and *Ihlea punctata* (Brandon et al., 2019). In general, salps are an important component of open ocean and coastal ecosystems, serving as a significant pathway for oceanic carbon flux (i.e., providing fast sinking fecal pellets and dead tunics to the benthos) (Bruland and Silver, 1981; Smith et al., 2014), exhibiting the highest filtration rates of all marine zooplankton filter feeders (Alldredge and Madin, 1982), exhibiting rapid growth rates (Alldredge and Madin, 1982), and occasionally forming large swarms in coastal waters under optimal conditions (Henschke et al., 2014), that can persist for up to six months (Smith et al., 2014). Salps are non-selective filter-feeders and their size range of prey overlaps with the majority of plastic in the ocean (Chan and Witting 2012, Goldstein et al. 2013). It is of note that salps in this region are often caught in nets or found in fish stomachs as empty barrels, lacking their internal organs, after hyperiid amphipods such as *Phronima sedentaria* have eaten their organs and used their barrels as brood pouches (Portner et al. 2017).

Recent observational data for the NPSG are limited. The Ocean Cleanup conducted a test of the original Ocean Cleanup System (System 001) in the NPSG in 2018, as reported by Ferrari (2019). More than 200 inspections were performed over the 115-day campaign period, with no recurring accumulations of pelagic and/or neustonic species. During one observation, a limited aggregation of *V. velella* (i.e., <250 individuals) was observed; no other species of buoyant or neutrally buoyant zooplankton were observed accumulating in the vicinity of the system.

4.3.2.2 Ichthyoplankton Neuston

Chen et al. (2018), assessing the level of pollutants in plastics present within the NPSG, also provided peripheral data regarding the relative proportion of plastics vs. neuston, as well as summarizing the neuston species collected. Chen et al. (2018) estimated that in the NPSG surface waters, the dry mass of buoyant plastics >0.5 mm was found to be ~180 times higher than the dry mass of biota >0.5 mm (i.e., plastic/biomass ratio average=180.7, max=448.5, min=15.0, std=127.7). These findings corroborate earlier findings of Moore et al. (2001).

Biota collected by Chen et al. (2018) during the neuston sampling effort included copepods, the marine insect *Halobates* spp., flying fish, lanternfish, jellyfish, salps, *Velella* spp., *Janthina* spp., and eggs. When only the 0.5 to 5 mm-sized material was considered, authors estimated that the dry mass of buoyant microplastics was 40 times higher than that of neustonic plankton (i.e., microplastic/plankton ratio average=39.7, max=143.0, min=4.6, std=38.3). The study authors also expressed caution regarding these preliminary results (i.e., the microplastic to plankton ratio), as some plankton groups are quite fragile and neuston biomass could have been underestimated.

Doyle (1992) characterized the neustonic ichthyoplankton collected off Washington, Oregon, and northern California during the 1980s, within the northern region of the CCS. While this summary is not directly applicable to the NPGP, a review of the data does provide insight into the potential presence of neustonic ichthyoplankton in the study area of interest, within the NPSG. Doyle (1992) described a neustonic assemblage of fish eggs, larvae, and juveniles, with highest species diversity evident over the shelf and continental slope. Diel variation in the occurrence and abundance of certain species of fish larvae in the neuston samples was also evident. Three categories were apparent among the neustonic ichthyoplankton:

- Obligate members: including larvae and early juveniles of nine species that occurred permanently and almost exclusively in the neuston but were scarce or absent in subsurface samples.
- Facultative members: including other taxa of larvae and juveniles which are abundant at the surface only at night.

- Stray members: including several taxa of fish eggs that accumulate at the surface because of positive buoyancy.

Fish larvae in the neuston were larger overall than those deeper in the water column; this is advantageous in terms of seeking prey and avoiding predators. Juveniles were also common in the neuston, but recently hatched larvae were largely absent (Doyle, 1992).

4.3.2.3 Rafting Neuston

The neuston of the NPSG region, while lacking a distinct pelagic algae component evident in other oceans (e.g., North Atlantic), does exhibit species found in association with floating debris. Termed the rafting assemblage, this community may have originated in association with naturally-occurring substrates such as terrestrial floating debris (e.g., logs), volcanically-derived pumice, and marine megafauna (e.g., turtles; Thiel and Gutow, 2005a,b). Goldstein (2012) cites several examples of these fauna, including the epipelagic crab *Planes* spp., commonly found on both flotsam and as an epibiont of olive ridley sea turtles (*Lepidochelys olivacea*; Frick et al., 2011); lepadomorph barnacles have also been found both in association with abiotic and biotic flotsam (Cheng and Lewin, 1976). Representative rafting species are summarized in **Table 4-3**, as adapted from Goldstein (2012).

While floating algae are absent from the NPSG, the presence of photosynthetic epibionts has been noted in association with floating debris. Bryant et al. (2016) documented elevated chlorophyll a (Chl a) on the surface of floating debris in the NPSG. Chl a measurements, combined with oxygen production and respiration measurements, demonstrated that metabolically active photosynthetic and heterotrophic organisms were attached to plastic debris. Chl a concentrations measured on the plastic debris ranged from approximately 0.03 to 0.42 mg m^{-2}, while Chl a concentrations in the surrounding seawater ranged from approximately 0.04 to 0.10 mg m^{-3}. Similarly, the microbial communities present on the surface of microplastics are genetically unique from those in the surrounding water column (Amaral-Zettler et al., 2015).

Rafting materials are frequently dominated by three lepadomorph barnacle species – *Lepas anatife*ra, *L. pacifica*, and *L. (Dosima) fascicularis*. *L. (Dosima) fascicularis* must settle onto a floating object but is able to form its own float at the end of the juvenile stage and drift independently thereafter (Newman and Abbott, 1980), although others can be present.

The species of *Lepas* are omnivorous, feeding opportunistically on the neustonic zooplankton. Bieri (1966) noted that *L. anserifera* has a multitude of food sources unlike any other found within the neuston. Lepadomorph barnacles are also prey for omnivorous epipelagic crabs (*Planes* spp.) and the rafting nudibranch *Fiona pinnata* (Bieri, 1966; Davenport, 1992). In the NPSG, Goldstein and Goodwin (2013) documented the presence of microplastics (<5 mm) in the gastrointestinal tract of *Lepas* spp., where more than one third of the specimens analyzed contained microplastics. Other conspicuous inhabitants of the rafting community are the cheilostome bryozoans (Winston et al., 1997), the barnacle-associated parasitic polychaete *Hipponoe gaudichaudi* (Cheng, 1975), and the isopod *Idothea* spp. (Herring, 1969; Gutow et al., 2006).

Table 4-3. Rafting taxa found in association with floating plastics in the North Pacific (Adapted from: Goldstein, 2012).

Phylum	Class	Order	Lowest Practical Taxonomic Level	Year(s) Observed	Previously Documented as Rafting
Annelida	Polychaeta	Aciculata	*Eunice* spp.	c	[1]
		Amphinomida	*Amphinome rostrata*	c	[1]
			Hipponoe gaudichaudi	a,b	[1]
		Phyllodocida	*Halosydna* spp.	b	N
			Nereididae	c	[1]
			Nereis spp.	c	[1]
			Phyllodocidae	c	[1]
		Sabellida	*Salmacina* spp.	c	N
			Subfamily Serpulinae	c	[1]
			Subfamily Spirorbinae	a,c	[1]
Arthropoda	Malacostraca	Amphipoda	*Caprella* spp.	a,c	[1]
			Elasmopus spp.	a	[1]
			Hyalidae	a	[1]
			Isaeidae	b	N
			Pleustidae	c	N
			Sphaeromatidae	a	[1]
			Stenothoidae	a	[1]
			Suborder Gammaridea	c	[1]
		Decapoda	*Chorilia* spp.	c	N
			Herbstia spp.	c	N
			Megalopae	b	[1]
			Palaemon affinis	c	[1]
			Pilumnus spp.	c	N
			Plagusia spp.	c	[1]
			Plagusia squamosa	a	[1]
			Planes cyaneus	a,c	[1]
			Planes minutus	a	[1]
			Planes spp.	b,c	[1]
		Isopoda	Cirolanidae	a	[1]
			Idotea spp.	a,b,c	[1]

Table 4-3. (Continued).

Phylum	Class	Order	Lowest Practical Taxonomic Level	Year(s) Observed	Previously Documented as Rafting
Arthropoda	Hexanauplia	Harpacticoida	Harpacticoida	a	[1]
		Kentrogonida (Rhizocephala)	*Heterosaccus* spp.	c	N
		Lepadiformes	Barnacle cyprids	a	[1]
			Lepas anatifera	a,c	[1]
			Lepas pacifica	a	[1]
			Lepas spp.	a,b,c	[1]
		Sessilia	*Amphibalanus amphitrite*	b	[1]
			Chthamalus spp.	c	N
			Megabalanus rosa	c	N
		Siphonostomatoida	*Chlamys* (*Perissopus*) spp.	c	[1]
	Pycnogonida	Pantopoda	*Phoxichilidium quadradentatum*	a	N, may encyst in hydroids[2]
		Unknown	Unknown	c	[1]
Bryozoa	Gymnolaemata	Cheilostomatida	*Bugula* spp.	a,b,c	[1]
			Jellyella eburnean	a	[1]
			Jellyella tuberculate	a	[1]
			Jellyella/*Membranipora*	b,c	[1]
			Membranipora (*Arbopercula*) *tenella*	a	[1]
		Ctenostomatida	*Bowerbankia* (*Amanthia*) spp.	a	[1]
			Victorella spp.	a	N, may disperse through fragmentation of substrate[3]
	Stenolaemata	Cyclostomatida	*Filicrisia* spp.	a	N
			Stomatopora spp.	a	N
			Tubulipora spp.	a	[1]

Table 4-3. (Continued).

Phylum	Class	Order	Lowest Practical Taxonomic Level	Year(s) Observed	Previously Documented as Rafting
Chordata	Actinopterygii	Perciformes	*Abudefduf* spp. *(vaigiensis?)*	b,c	N/A
			Canthidermis maculata	c	N/A
			Chirolophis spp.	c	N/A
			Coryphaena hippurus	b	N/A
			Elagatis bipinnulata	b	N/A
			Histrio histrio	c	N/A
			Kyphosus spp. *(vaigiensis?)*	b,c	N/A
			Meiacanthus spp.	c	N/A
			Seriola rivoliana	c	N/A
	Unknown	Unknown	Beige fish eggs	c	[1]
			Blue fish eggs	c	[1]
			Fish eggs	a,b	[1]
Ciliophora	Heterotrichea	Heterotrichida	*Halofolliculina* spp.	c	N on plastic, documented on wood[4]
Cnidaria	Anthozoa	Actiniaria	Actiniidae	b	[1]
			Anthopleura spp.	a,b	N, may disperse through detachment[5]
			Calliactis sp.	c	N
			Metridium spp.	a	N, may disperse through detachment[5]
			Hormathiidae	c	[1]
		Scleractinia	stony coral	b	[1]
	Hydrozoa	Leptothecata	*Clytia gregaria*	a	N, though nine other *Clytia* species documented as rafting[1]
			Obelia spp.	a	[1]
			Plumularia setacea	a	[1]
		Unknown	hydroid	b,c	[1]
Echinodermata	Ophiuroidea	N/A	Ophiuroidea sp. 1	c	Not determined
			Ophiuroidea sp. 2	c	Not determined
			Ophiuroidea sp. 3	c	Not determined
Foraminifera	Globothalamea	Rotaliida	*Planulina ornata*	a	N

Table 4-3. (Continued).

Phylum	Class	Order	Lowest Practical Taxonomic Level	Year(s) Observed	Previously Documented as Rafting
Mollusca	Bivalvia	Arcida	Arcidae	c	N
		Myida	*Teredo* spp.	c	[1]
			Zirfaea spp. *(pilsbryi?)*	b	N
		Mytilida	*Mytilus galloprovincialis*	a,c	[1]
		Ostreida	*Crassostrea* (*Magallana*) *gigas*	b,c	[1]
			Pinctada spp.	c	[1]
		Unknown	Lower valve of oyster	c	[1]
	Gastropoda	Caenogastropoda	*Litiopa melanostoma*	c	[1]
		Littorinimorpha	*Erronea* spp.	c	N, may have widespread larval transport[6]
		Nudibranchia	*Fiona pinnata*	a,b,c	[1]
			Fiona pinnata eggs	a	[1]
		Pleurobranchida	*Berthella* spp.	c	N
		Superfamily Pyramidelloidea	*Odostomia (Evalea) tenuisculpta*	a	N
Platyhelminthes	Rhabditophora	Polycladida	Rhabditophora (Polycladida)	c	[1]
		Rhabdocoela	Rhabdocoela	c	[1]
	Turbellaria (Platyhelminthes)	Unknown	flatworm	a,b	[1]
			flatworm	b	[1]
Porifera	Calcarea	Leucosolenida	*Sycon* spp.	b,c	N
	Demospongiae	Suberitida	*Halichondria panicea*	a	N

Key:
a – Eastern Pacific 2009
b – Eastern Pacific 2011
c – Western Pacific 2012
N – Not listed as rafting in the scientific literature
[1] – listed in Thiel and Gutow, 2005a,b
[2] – listed in Lovely, 2005
[3] – listed in Carter et al., 2010
[4] – listed in Matthews, 1963
[5] – listed in Riemann-Zürneck, 1998
[6] – listed in Emerson and Chaney, 1995.
Note: Taxonomic nomenclature updated to 2021; revised per World Register of Marine Species (e.g., parenthetic entries, exclusive of ?) (www.marinespecies.org)

4.3.2.4 Spatial and Temporal Distribution Patterns of Neuston

Thibault (2021) notes that dispersal drives the exchange of genetic material among marine populations, with diverse ecological and evolutionary consequences including species range limits, connectivity, and the potential for local adaptation. Population genetic connectivity can be maintained by the exchange of very few larvae (Strathmann et al., 2002; Swearer et al., 2002; Burgess et al., 2015), rendering it extremely sensitive to disruptions in larval dispersal. Furthermore, larval supply is an important supply-side factor that affects population dynamics, interaction strengths, and the resilience of communities (Menge et al., 1997; Navarrete et al., 2005; Palardy and Witman, 2014; Bashevkin et al., 2020). However, the fate and survivability of pelagic larvae is dangerous and uncertain, as they contend with strong currents, patchy food supplies, predators, and environmental variation before finding a suitable nursery or adult habitat (Morgan, 1995; Llopiz et al., 2014). In addition, larvae are generally more sensitive to stressors than adults (Byrne, 2011; Harvey et al., 2013; Kroeker et al., 2013; Przeslawski et al., 2014; Pandori and Sorte, 2019), making them especially vulnerable to global climate change.

A comprehensive characterization of the spatial and temporal distribution patterns of neuston in the NPSG is lacking. For those rafting neuston species found in association with marine debris, including both natural materials and plastics, distribution patterns follow the patterns exhibited by the debris itself. Important rafting species include lepadomorph barnacles (*Lepas* spp.), epipelagic crabs (*Planes* spp.), the rafting nudibranch *Fiona pinnata*, cheilostome bryozoans, the barnacle-associated parasitic polychaete *Hipponoe gaudichaudi*, and the isopod *Idothea* spp.Distribution patterns for the free-floating neuston are less well known. Drifting neuston include the siphonophore *Physalia physalis*, chondrophores *Velella velella* and *Porpita porpita*, nudibranchs *Glaucus atlanticus* and *Glaucilla* spp., the prosobranch gastropod *Janthina* spp., the gerrid insect *Halobates* spp. (although their eggs are deposited on rafting substrates, and thus would follow the distribution of those floating materials; Goldstein et al. 2012), and pontellid copepods, plus various ichthyoplankton taxa. *Glaucus atlanticus* has a cosmopolitan subtropical distribution; cryptid species of *Glaucus spp.* have recently been differentiated and *Glaucus mcfarlenei* and *Glaucus thompsoni* are only currently known in the North Pacific (Churchill et al., 2014). Diel vertical migration has also been exhibited by various species; in general, there is a significant increase in neuston diversity at night (David, 1967; Harbison and Campenot, 1979; Hobbs and Botsford, 1992). One such diel vertically migrating species is the abundant neon flying squid, *Ommastrephes bartramii*, which migrates from between 36° and 46°N latitude in the summer and fall to 25° and 35°N in the winter when spawning occurs (Ichii et al., 2009).

In the subtropical Northeast Atlantic, density estimates for invertebrate neuston were measured at only 25 specimens per 100 m^3 around midday, with that number expected to be higher at night (Weikert, 1974).

Egger et al. (2021) recently summarized observational data acquired in 2019, reporting on the relative spatial and temporal distribution patterns for both floating plastic debris (i.e., 0.05 to 5 cm in size) and neuston present in the NPSG. Data provide an indication of how the neuston community is distributed relative to plastic pollution in the study area, further supplementing data acquired between 2015-2019 (Egger et al., 2020a,b). Summary results for important neuston species are provided in **Table 4-4**. No individuals of *V. velella* were observed in the outer boundaries of the NPSG by Egger et al. (2021), although this species was observed both inside and outside the NPSG. The dominant fish species observed were Pacific saury (*Cololabis saira*) and Lanternfish (Myctophidae).

Table 4-4. Summary of neuston species density within and outside the North Pacific Subtropical Gyre (Adapted from: Egger et al., 2021).

Species/Taxa	Abundance (number of individuals)		Density (number of individuals km^{-2})	
	Outside the NPSG	Inside the NPSG	Outside the NPSG	Inside the NPSG
V. velella	110,962	639	61,541–133,935	557–855
Halobates spp.	15,033	16,650	11,227–25,493	9,429–32,655
J. janthina	3,315	1,897	2,124-9,363	542–4,566
P. porpita	Not observed	95	Not observed	91–678
Glaucus spp.	1	<1,000	1	<1,000
P. physalis	1	Not observed	N/A	Not observed
Copepods	1,230	397,079	Not reported	43,545–1,731,593
Amphipods	740-3,818		643-6,939	
Pteropods, isopods, heteropods	Not observed	561–659	Not observed	187–4,654
Crabs	1,255	959–1,550	1,785	604–3,501
Squid	908	747–1,069	555	371–588
Euphausiids, shrimp	1,840	592–1,975	9,991	570–25,320
Fish	1,171–2,105		622–4,949	

4.3.2.5 Other Relevant Studies

Moore et al. (2001) summarized the results of 11 neuston tows completed during August 1999 in the NPSG. A total of 152,244 planktonic organisms weighing approximately 70 g were collected from the surface waters near the central pressure cell of the North Subtropical High in the gyre, with a mean abundance of 1,837,342 organisms km^{-2} and mean mass of 841 g km^{-2} (dry weight). Abundance estimates were quite variable, ranging from 54,003 organisms km^{-2} to 5,076,403 organisms km^{-2}; estimated weights were also highly variable, ranging from 74 to 1,618 g km^{-2}. Plankton abundance was higher than plastic abundance in 8 out of 11 samples, with the difference being much higher at night. Two filter-feeding salps (*Thetys vagina*) were also collected in this study.

Per Olivar et al. (2014), the vertical distribution of neustonic fish assemblages present in the Pacific, Atlantic, and Indian oceans is primarily controlled by light. Fish assemblages are routinely dominated by late-larvae and juveniles of Exocoetidae (flying fish), Hemiramphidae (halfbeaks), and Scomberesocidae (sauries) during the day. At night, the vertical migration of mesopelagic species changes the dominance pattern in favor of Myctophidae (lanternfish) and Scomberesocidae.

Batten et al. (2010) published a compendium of physical, chemical, and biological data for the Pacific's oceanic region for the 2003-2008 period, including data for the NPSG, the latter of which supports a diverse assemblage of apex predators including tunas, billfishes, sharks, marine mammals and seabirds. While the data review provides a general synopsis of mesoscale trends within the North Pacific, it did not include specific information regarding the neuston of the region.

Though the majority of plastic debris in the North Pacific is in the form of small fragments (Hidalgo-Ruz et al., 2012), these particles carry few large taxa, most of which are known subtropical rafters such as *Jellyella* or *Membranipora* bryozoans, but they carry a thriving community of bacteria and microbes (Zettler et al., 2013; Amaral-Zettler et al., 2015). Goldstein (2012) found the majority of potentially invasive taxa (e.g., non-indigenous species), such as the majid crab *Herbstia*, on large items such as net balls, though she found the coral pathogen *Halofolliculina* spp. on medium-sized plastic fragments (0.03-0.1 m^2). Since then, microplastics have been found to be vectors of pathogens like *Vibrio* (Zettler et al., 2013; Kirstein et al., 2016) and *Aeromonas salmonicida* (Virsek et al., 2017). Selective removal of medium to large plastic debris objects may provide a degree of protection to coastal habitats where the potential invasion of nonindigenous species is of concern, but some pathogens may remain on microplastics.

4.2.3.6 Energy Flow in the Pelagic Ecosystem and the Relative Contribution from Neuston

Goldstein (2012) suggests that plastic-associated rafting organisms may be affecting the pelagic ecosystem by reworking the particle size spectrum through ingestion and egestion (also see Mook, 1981). Suspension-feeding rafting organisms prey on a variety of particle sizes, from 3 to 5 µm for *Mytilus* mussels (Lesser et al., 1992), 10 to 20 µm for bryozoans (Pratt, 2008), 20 to 125 µm for caprellid amphipods (Caine, 1977), 0.5 mm to >1 mm for lepadid barnacles and hydroids (Evans, 1958; Boero et al., 2007), and the very wide range of <1 µm to 1 mm for salps (Madin, 1974; Vargas and Madin, 2004). This size range encompasses a significant portion of the non-microbial particle size spectrum of the oligotrophic North Pacific (Sheldon et al., 1972). Because particle size determines which energy pathway benefits – either the microbial loop or the metazoan food web, Karl et al. (2001) noted that any large-scale alterations in particle size could substantially influence the species composition of the NPSG. Size-related preferences for one component of the neuston – salps – has been recently addressed by Brandon et al. (2019).

The ecological role of plastic-associated rafting assemblages on the open ocean ecosystem remains unclear. Increased concentrations of *Halobates* have been noted (e.g., Majer et al., 2012; Goldstein, 2012). Goldstein (2012) notes that the most abundant large-bodied plastic-associated rafting organisms, the lepadid barnacles, may not be sufficiently abundant to consume a significant portion of neustonic zooplankton biomass. Nevertheless, macroplastics floating on the ocean surface provides settling substrate and habitat for a diversity of coastal and open ocean organisms in the pelagic environment.

4.3.3 Fish/Fishery Resources

4.3.3.1 Coastal and Estuarine Species

Numerous species of fish utilize the Strait of Juan de Fuca and the Strait of Georgia due to their critical location as a passageway from the open ocean to estuarine and inland waterways in Washington and Canada. Nearshore beach seine surveys, conducted over a 9 year period by Frick et al. (2018), identified 45 to 55 species of fish per year, with the catch numerically dominated by three species of forage fish: *C. pallasi*, *A. hexapterus*, and *Hypomesus pretiosus* (surf smelt).

Pelagic trawl surveys conducted by Burger et al. (2020) in 2016 and 2017 in the United States portion of the Strait of Juan de Fuca and tributaries identified 96 different species of fish and invertebrates. However, similar to other studies, the catch was dominated by forage fish with just nine species comprising 96% of the individuals collected. Dominant species were *C. pallasii*, *M. productus*, *Cymatogaster aggregata* (shiner perch), and *Doryteuthis opalescens* (market squid).

The only coastal fish species listed under Schedule I of SARA is the yelloweye rockfish (*Sebastes ruberrimus*) which is listed as Threatened. Fourteen species of sharks are known from the waters of British Columbia (Fisheries and Oceans Canada, 2011), including the basking shark (*Cetorhinus maximus*) which is listed under Schedule I of SARA as Endangered. Fourteen species of skates and rays are also known from British Columbian waters (Fisheries and Oceans Canada, 2012), but none are listed in Schedule I of SARA. **Table 4-5** describes some of the common species found in the coastal and estuarine habitat of the Vancouver area.

Table 4-5. Examples of species found within coastal and estuarine habitats in the Vancouver area.

Common Name	Scientific Name	Species Details
Alaska Pollock	*Gadus chalcogrammus*	• Widely distributed in the North Pacific, with the largest populations found in the Bering Sea. • Foraging species, but primary food sources consisting of copepod plankton and krill. • Commercially important species.
Chinook Salmon	*Oncorhynchus tshawytscha*	• Migratory species. • Distributed in North America from the Monterey Bay area of California to the Chukchi Sea area of Alaska. • Hatch in freshwater streams and rivers and migrate to the open ocean to feed. • After a few years feeding in the ocean, they return to the streams or rivers to spawn, generally in summer or early fall.
Chum Salmon	*Oncorhynchus keta*	• Migratory species. • Distributed in the North Pacific (i.e., Korea, Japan, Okhotsk, Arctic Alaska, south to San Diego, California). • Spawns from late summer to March, with peak spawning in early winter when the river flows are high. • Hatch in freshwater streams and rivers and migrate to the open ocean.
Sockeye Salmon	*Oncorhynchus nerka*	• Migratory species, although some populations live entire lives in freshwater. • Spawns in late summer or fall in British Columbia. • Distributed in North Pacific Ocean and its tributaries. • Hatch in freshwater streams and rivers and migrate to the open ocean to feed.
Coho Salmon	*Oncorhynchus kisutch*	• Migratory species. • Occurs in the North Pacific Ocean and in most coastal streams and rivers from Alaska to central California. • Spends 1 to 2 years feeding in the ocean, then returns to their natal streams or rivers to spawn, generally in fall or early winter.
Pacific Denver Sole	*Microstomus pacificus*	• Found in the Pacific Ocean from the Bering Sea and western Aleutian Islands to southern Baja California. • Dover sole live near the ocean floor and prefer soft bottom habitat in waters up to 1,400 m (4,593 ft) deep. • Spawning seasons vary by location and larvae usually settle to the bottom after a year of living in the upper water column.
English Sole	*Parophrys vetulus*	• Spawn from winter to early spring over soft muddy ocean floors in water 50 to 70 m (164 to 230 ft) deep. • After spawning, this species travels north to summer feeding grounds and returns south in the fall.
Flathead Sole	*Hippoglossoides elassodon*	• Migrate in winter along the outer continental shelf to feeding grounds in shallower water in the spring. • Spawning occurs from February to April in deeper waters.
North Pacific Hake	*Merluccius productus*	• Found from the northern portion of Vancouver Island south to the northern portion of the Gulf of California. • Most abundant groundfish in the California Current System, with more hake caught than all other groundfish combined. • Populations also exist in major Pacific Ocean inlets, including the Strait of Georgia. • Commercially important species.
Surf smelt	*Hypomesus pretiosus*	• Found from Prince William Sound in Alaska south to southern California. • Nighttime spawning occurs in summer and fall (May to October). • Important fish as part of the diet of several salmon species.

Table 4-5. (Continued).

Common Name	Scientific Name	Species Details
Pacific Herring	*Clupea pallasii*	• Found from the Bering Sea south to Baja California. • Pacific fishery collapsed in the early 1990s but is slowly recovering to viability. • Considered a keystone species in the Pacific northwest. • Spawns variably throughout the year, but usually in intertidal submerged vegetation habitats.
Pacific Mackerel	*Scomber japonicus*	• Found from southeastern Alaska to Mexico. • Mackerel perform inshore/offshore migration, with numbers increasing near the California coast from July to November. • Spawning timing varies depending on location, but often occurs from late April to September off California. Spawning is year-round off central Baja California, peaking from June through October. • Commercial valuable species.
Pacific Sardine	*Sardinops sagax*	• Juvenile sardines perform a northward return migration, taking advantage of the surface manifestation of the poleward flowing California Undercurrent to assist migration (Weber et al., 2015).
Yelloweye Rockfish	*Sebastes ruberrimus*	• Found from Dutch Harbor, Alaska south to Baja California. • Prized for their high-quality meat fillet which has led to overfishing. • Extremely long-lived species with lifespans estimated of up to 120 years.
Market Squid	*Doryteuthis opalescens*	• Spawning occurs April through October in central California and October through the end of April or May in southern California. • Spawning squid congregate in large schools near their spawning grounds, usually over sandy habitats. • The California market squid fishery is strongly affected by environmental and atmospheric conditions of the California Current System as well as El Niño/La Niña events. • Overall catches can be decreased during El Niño but then rebound with the increased upwelling of cooler La Niña phases (Pacific Fishery Management Council, 2017; Jackson and Domeier, 2003).

4.3.3.2 Oceanic Species

Oceanic or epipelagic fishes generally inhabit the upper 200 m (656.2 ft) of the water column. The group is defined by sharks (Carcharhinidae, Lamnidae, Rhincodontidae), billfishes (Istiophoridae, Xiphiidae), tunas (Scombridae), dolphinfishes (Coryphaenidae), flyingfishes (Exocoetidae), halfbeaks (Hemiramphidae), opahs (Lampridae), oarfishes (Regalecidae), jacks (Carangidae), remoras (Echeneidae), pomfrets (Bramidae), driftfishes (Stromateidae), molas (Molidae) and triggerfishes (Balistidae)(e.g., Parin, 1968). A number of these species such as dolphinfish (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), striped marlin (*Kajikia audax*), blue marlin (*Makaira nigricans*), and tunas (*Thunnus* spp.) are important to commercial and/or recreational fisheries. Many epipelagic species migrate great distances within or outside the central Pacific. For example, blue marlins will migrate across the entire Pacific in response to seasonal changes in sea-surface temperature and productivity (Carlisle et al., 2016). Yellowfin tuna (*Thunnus albacares*) and albacore (*Thunnus alalunga*) migrate across the northern Pacific seeking preferred water temperatures and food resources (Collette and Graves, 2019). **Table 4-6** presents distribution, migration pattern, and spawning details for some of the common species found near the NPSG and the CCS.

Table 4-6. Distribution, migration pattern, and spawning details for some of the common species found near the North Pacific Subtropical Gyre and the California Current System.

Common Name	Scientific Name	Species Details
Yellowfin Tuna	*Thunnus albacares*	• Highly migratory species. • Spawning occurs in the southeastern Pacific, near Central America, during January and February. • Commercially important.
Skipjack Tuna	*Katsuwonus pelamis*	• Found worldwide in waters warmer than 15°C. • Spawning occurs in the eastern Pacific in the summer months. • Commercially important.
Bigeye Tuna	*Thunnus obesus*	• Highly migratory species. • Distributed across the Pacific, but the bulk of the catch is made toward the eastern and western ends of the basin. • Spawns in Equatorial South Pacific between April and September. • Commercially important.
Albacore Tuna	*Thunnus alalunga*	• Typically conducts an expansive annual migration that begins in spring or early summer waters off Japan, continues throughout late summer into inshore waters off the United States Pacific coast, and ends late in the year in the western Pacific Ocean. • Spawning takes place in the mid-Pacific. • Large specimens caught northwest of the Hawaiian Islands in late summer carry nearly ripe eggs in their ovaries. • Fishing for Albacore takes place in waters 37 to 185 km (20 to 100 nmi) offshore central and southern California.
Pacific Bluefin	*Thunnus orientalis*	• Juveniles migrate to Eastern Pacific waters late in the first or second year of life. • Commercially important.
Wahoo	*Acanthocybium solandri*	• Found worldwide in tropical and subtropical waters. • Popular game fish.
Striped Marlin	*Kajikia audax*	• Highly migratory species. • Abundant off the coast of California during summer from July to October.
Swordfish	*Xiphias gladius*	• Highly migratory species. • Occur worldwide in tropical and temperate seas. • Most encountered between the mainland and the Channel Islands off southern California. • Spawning occurs offshore Hawaii from April until July.
Yellowtail Amberjack	*Seriola lalandi*	• Distributed from Chile to Canada. • Spawning occurs from June through October.
Dolphinfish	*Coryphaena hippurus* *Coryphaena equiselis*	• Highly migratory species. • Distributed widely in all oceanic waters, including coastal and open ocean areas. • Commercially important species that are usually caught by tuna troll lines and occasionally by purse-seines and driftnets.
Great White Shark	*Carcharodon carcharias*	• Found along the Pacific coast for most of the year. • In the spring, a migration pattern occurs, and the sharks move west into the open ocean and congregate approximately halfway between Hawaii and California (Jorgenson et al., 2009) within an area called *white shark café* possibly for reproduction or feeding. White sharks stay at the *café* from April to July.
Spinetail Devil Ray	*Mobula* sp.	• The southern Gulf of California serves as an important spring and summer mating/feeding ground for adults. • Pupping takes place offshore around offshore islands or seamounts.
Shortfin Mako Shark	*Isurus oxyrinchus*	• Rare in British Columbia waters. • Tends to follow movements of warm water poleward in the summer.
Oceanic Whitetip	*Carcharhinus longimanus*	

Table 4-6 (Continued).

Common Name	Scientific Name	Species Details
Silky Shark	*Carcharhinus falciformis*	• Common bycatch of longline, purse-seine, and hand line fisheries worldwide.
Blue Shark	*Prionace glauca*	• Caught in the North Pacific as bycatch in the giant flying squid fishery by becoming entangled while preying on squids. • Commonly caught with hook and lines, pelagic trawls, and bottom trawls.

<u>Flotsam-Associated Fishes</u>

Floating seaweed, jellyfishes, siphonophores, trees, logs, and artificial debris attract juvenile and adult epipelagic fishes (Gooding and Magnusen, 1967; Hunter and Mitchell, 1967; Hunter and Mitchell, 1968; Thiel and Gutow, 2005a,b; Nelson, 2003; Goldstein et al., 2014). The reasons for attraction to flotsam are not well known but likely involve shelter, feeding opportunities, and need for a reference point in an otherwise featureless ocean (Castro et al., 2002). Most common species are from the jack and triggerfish families. Other common families in the open ocean flotsam assemblage include halfbeaks, flyingfishes, chubs (Kyphosidae), tripletails (Lobotidae), damselfishes (Pomacentridae), frogfishes (Antennariidae), and filefishes (Monacanthidae). Over 300 species are documented to associate with living or dead flotsam in shelf waters worldwide (Castro et al., 2002). In open ocean waters of the Pacific 29 species from 20 families were documented by Parin and Fedoryako (1999).

The spatial relationships and orientation of fishes with the floating objects vary with fish size and life stage (Parin and Fedoryko, 1999; Castro et al., 2002). Parin and Fedoryako (1999) described three behavioral groups of flotsam-associated fishes broadly defined by body size (small, intermediate, and large). Small individuals (<12 cm total length) including early life stages with limited swimming abilities, associate intimately with the flotsam staying within about 50 cm of most objects. Examples include flyingfishes, sargassumfish (*Histrio histrio*), tripletail (*Lobotes surinamensis*), damselfishes (*Abudefduf* spp.), and dolphinfishes (*Coryphaena* spp.). Most of these individuals are juveniles, often cryptically colored, and will seek interstitial spaces within natural or artificial floating objects. Flyingfishes will deposit eggs on floating plant material. This group highlights the fact that flotsam serves as a nursery area for many oceanic (and coastal) species.

Intermediate-sized fishes (3 to 12 cm total length) will remain within 2 to 3 m below the floating material but come closer at night or when frightened by potential predators. Juveniles and adults of this group are generally competent swimmers and exhibit counter-shading (light below, dark above) instead of cryptic coloration. Common members of this group include jacks (*Caranx* spp., *Carangoides* spp., *Seriola* spp., and *Naucrates ductor*), driftfishes (*Psenes* spp.), subadult dolphinfishes, and chubs (*Kyphosus* spp.).

Larger (0.5 to >1.0 m total length) highly mobile predatory species such as sharks (*Carcharhinus falciformis*; *C. longimanus*), dolphinfishes, rainbow runner (*Elagatis bipinnulata*), amberjacks (*Seriola* spp.), and tunas (*Thunnus albacares*, *Katsuwonus pelamis*) may range from 2 to >10 m from the floating material. The propensity of tuna and dolphinfishes for floating material has affected the behavior of commercial fisheries in some regions (e.g., Caddy and Majkowski, 1996)

<u>Mesopelagic fishes</u>

Below the epipelagic zone the water column may be layered into mesopelagic (200 to 1,000 m) zone. In the mesopelagic zone fish assemblages are numerically dominated by lanternfishes (Myctophidae), bristlemouths (Gonostomatidae), and hatchetfishes (Sternoptychidae) (Sutton et al., 2017). Lanternfishes are small silvery fishes that can be extremely abundant, often responsible for the deep scattering layer in sonar images of the deep sea. Lanternfishes, and other mesopelagic fishes spend the daytime in depths of 200 to 1,000 m (656.2 to 3,280.8 ft), but migrate vertically at night into food rich, upper water column. Some species will reach near-surface waters during their nocturnal forays. Mesopelagic fish, while less commonly known, are important ecologically because they transfer significant amounts of energy between mesopelagic and epipelagic zones over each daily cycle. The lanternfishes are important prey for meso- and epipelagic predators such as seabirds, tunas, swordfish, and marine mammals (Choy et al., 2015; Davison and Asch, 2011).

Fish observations were not quantified during The Ocean Cleanup's transit and deployment of System 001 in 2018, but numerous flyingfishes, dolphinfishes, sunfish, and yellowfin tunas were observed (Seiche, 2019). During The Ocean Cleanup's deployment of System 001B in the NPSG in 2019, a total of 11 species of fish were observed in proximity of the deployed system, including: blue shark (*Prionace glauca*), dolphinfish (*Coryphaena hippurus*), California flying fish (*Cheilopogon pinnatibarbatus californicus*), blue marlin (*Makaira nigricans*; **Image 4-1**) ocean sunfish (*Mola mola*), pilotfish (*Naucrates ductor*), , striped marlin (*Kajikia audax*), Pacific sergeant major (*Abudefduf troschelii*), chubs (*Kyphosus* spp.), and yellow-tail amberjack (*Seriola lalandi*) (The Ocean Cleanup, 2020). Additionally, unidentified tuna, sharks, pufferfishes, and other unidentified large and small fishes were observed.

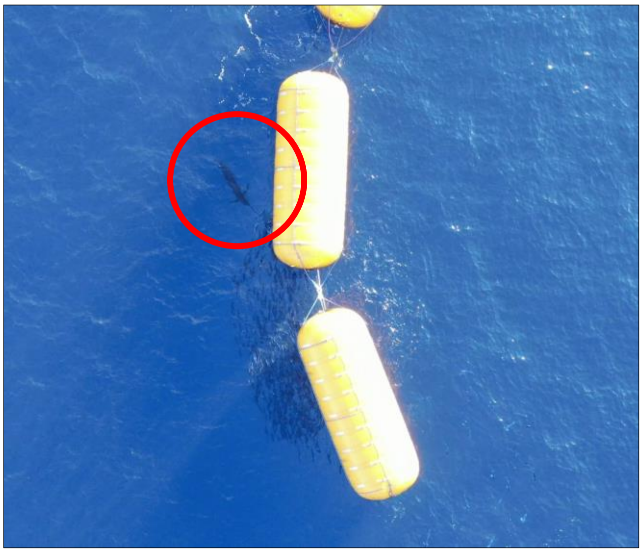


Image 4-1. Blue marlin swimming at depth (red circle) near The Ocean Cleanup's deployed System 001B in the North Pacific Subtropical Gyre in 2019. From: The Ocean Cleanup, 2020.

Numerous fish species that could occur in the area of deployment in the NPSG are classified by the IUCN (Red List), with the species of elevated concern listed as either Vulnerable, Endangered, or Critically Endangered. **Table 4-7** summarizes the Vulnerable or Endangered species that may be found in the open ocean in the vicinity of the S002 deployment.

Table 4-7. Species of pelagic fish that are classified as Vulnerable or Endangered that may be found in the vicinity of The Ocean Cleanup system deployment in the North Pacific Subtropical Gyre. Source: IUCN Red List, 2021.

Family	Common Name	Scientific Name	IUCN Red List Status	Typical Depth Range	Reference
Sphyrnidae	Great hammerhead shark	*Sphyrna mokarran*	Critically Endangered	Surface to 80 m (263 ft)	Rigby et al., 2019a
	Scalloped hammerhead shark	*Sphyrna lewini*	Critically Endangered	Surface to 275 m (902 ft)	Rigby et al., 2019b
	Smooth hammerhead shark	*Sphyrna zygaena*	Vulnerable	Surface to 200 m (656 ft)	Rigby et al., 2019c
Rhincodontidae	Whale shark	*Rhincodon typus*	Endangered	Surface to >1,900 m (>6,234)	Pierce and Norman, 2016
Lamnidae	Short fin mako shark	*Isurus oxyrinchus*	Endangered	Surface to 500 m (1,640 ft)	Rigby et al., 2019d
	Longfin mako shark	*Isurus paucus*	Endangered	Surface to 1,752 m (5,748 ft)	Rigby et al., 2019e
	Great White shark	*Carcharodon carcharias*	Vulnerable	Surface to 250 m (820 ft)	Rigby et al., 2019f
Molidae	Ocean sunfish	*Mola mola*	Vulnerable	Surface to 400 m (1,312 ft)	Liu et al., 2015
Molidae	Pelagic thresher shark	*Alopias pelagicus*	Endangered	Surface to 150 m (492 ft)	Rigby et al., 2019g
	Big eye thresher shark	*Alopias superciliosus*	Vulnerable	Surface to 725 m (2,379 ft), mostly below 100 m (328 ft)	Rigby et al., 2019h
	Common thresher shark	*Alopias vulpinus*	Vulnerable	Surface to 366 m (1,200 ft)	Rigby et al., 2019i
Carcharhinidae	Oceanic whitetip shark	*Carcharhinus longimanus*	Critically Endangered	Surface to 150 m (492 ft)	Rigby et al., 2019j
	Silky shark	*Carcharhinus falciformis*	Vulnerable	Surface to 500 m (1,640 ft)	Rigby et al., 2017
Cetorhinidae	Basking Shark	*Cetorhinus maximus*	Endangered	Surface to 1,000 m (3,300 ft)	Rigby et al., 2021
Mobulidae	Giant manta ray	*Mobula birostris*	Endangered	Surface to 120 m (394 ft)	Marshall et al., 2020a
	Spinetail devil ray	*Mobula mobular*	Endangered	Surface to 1,112 m (3,648 ft)	Marshall et al., 2020b
	Sicklefin devil ray	*Mobula tarapacana*	Endangered	Surface to 1,896 m (6,221 ft)	Marshall et al., 2019a
	Bentfin devil ray	*Mobula thurstoni*	Endangered	Surface to 100 m (328 ft)	Marshall et al., 2019b
Scombridae	Bigeye tuna	*Thunnus obesus*	Vulnerable	Surface to 1,500 m (4,921 ft)	Collette et al., 2011a
	Pacific bluefin tuna	*Thunnus orientalis*	Vulnerable	Surface to 550 m (1,804 ft)	Collette et al., 2014
Istiophoridae	Blue marlin	*Makaira nigricans*	Vulnerable	Surface to 1,000 m (3,280 ft)	Collette et al., 2011b

IUCN = International Union for Conservation of Nature.

4.3.4 Marine Mammals

During transit and deployment of The Ocean Cleanup's System 001 in the NPSG in 2018, a total of 62 marine mammal observations were made, including 52 sightings of cetaceans, 7 of pinnipeds, 2 of fissipeds, and one sighting of an unknown species, comprising a total of 16 unique identifiable species. Most marine mammals were observed during towing or transit operations (i.e. the vessel moving to and from port), with only a single sperm whale (**Image 4-2**) and sei whale observed during deployment in the NPSG. The most common identified marine mammal was the humpback whale, with 10 unique sightings, followed by the California sea lion and Common dolphin (5 sightings each) (Seiche, 2019). Observations were made from September 2018 to January 2019. Summarized marine mammal observation data from the 2018 transit and deployment are presented in **Table 4-8**.

Image 4-2. A sperm whale sighted during deployment of The Ocean Cleanup's System 001 in the North Pacific Subtropical Gyre in 2018. From: Seiche, 2019.

Table 4-8. Species or groups identified during transit and deployment of The Ocean Cleanup's System 001 in the North Pacific Subtropical Gyre in 2018. Adapted from: Seiche, 2019.

Species or Group	Number of Observations
Humpback whale	10
California sea lion	5
Common dolphin	5
Fin whale	3
Marine otter	2
Sperm whale	2
Short-finned pilot whale	2
Dall's porpoise	2
Dall's porpoise	2
Gray whale	2
Sei whale	1
Dolphins (Spinner and Common dolphins mixed)	1
Blue whale	1
Fur seal	1
Bottlenose dolphin	1
Harbour seal	1
Gray seal	1
Unidentified whale	7
Unidentified mysticete	7
Unidentified dolphin	4
Unidentified beaked whale	1
Unknown	1
Total	**62**

During transit and deployment of The Ocean Cleanup's System 001B in the NPSG in 2019, a total of 17 sightings were made of marine mammals including five sperm whale sightings, two humpback whale sightings, two groups of short beaked common dolphins (**Image 4-3**), one individual unidentified dolphin, one group of unidentified dolphins, one group of two unidentified whales, four groups of solitary unidentified whales, and one unidentified cetacean (The Ocean Cleanup, 2020). Observations were made between June and November 2019.

Image 4-3. A pod of short-beaked common dolphins bow-riding in front of The Ocean Cleanup's project vessel during transit to the North Pacific Subtropical Gyre in 2019. From: The Ocean Cleanup, 2020.

In the northeastern Pacific Ocean region, there are 42 species of marine mammals representing two taxonomic orders that may be present: Cetacea (baleen whales, toothed whales, dolphins, and porpoises) and Carnivora (true seals and eared seals) (Jefferson et al., 2008).

All marine mammals within waters under the jurisdiction of Canada are protected under the Marine Mammal Regulations promulgated under the Fisheries Act (see **Section 3.4**). Some species are further protected under SARA. Under SARA, a species is considered *endangered* if it is "a wildlife species that is facing imminent extirpation or extinction." A species is considered *threatened* if it "a wildlife species that is likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction." The Marine Mammal Regulations prohibit, with certain exceptions, disturbing or killing of any marine mammal.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an advisory panel to the Minister of Environment and Climate Change Canada that assesses the status of wildlife species at risk of extinction. COSEWIC is the regulatory body that makes recommendations for species to be listed as Endangered or Threatened under SARA.

The IUCN Red List provides taxonomic, conservation status, and distribution information on plants, fungi, and animals that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of extinction; the main purpose of the IUCN Red List is to catalogue and highlight those plants and animals that are facing a higher risk of global extinction (i.e., those listed as **Critically Endangered**, **Endangered**, **and Vulnerable**). The current SARA, COSEWIC, and IUCN status of each marine mammal species that may occur within the project area are provided in the following sections.

4.3.4.1 *Whales, Dolphins, and Porpoises (Order Cetacea)*

Baleen Whales *(Suborder Mysticeti)*

Eight species of baleen (mysticete) whales are known to occur in the waters of the North Pacific Ocean (**Table 4-9**). These include three species classified as **Endangered**, four as **Least Concern** and one as **Vulnerable** in the IUCN Red List (**Table 4-9**). The sei, blue, and North Pacific right whales are the Endangered species, the fin whale is listed as **Vulnerable**, while the minke, gray, Bryde's, and humpback are listed as species of **Least Concern**.

Table 4-9. Mysticete whales present from southwestern Canadian coast to the North Pacific Ocean.

Common Name	Scientific Name	Migratory	IUCN Red List Status[1]	SARA Status	COSEWIC Status	Reference
Common Minke Whale (North Pacific subspecies)	*Balaenoptera acutorostrata scammoni*	Yes, but some are present year-round	Least Concern	Not Listed	Not at Risk	Cooke, 2018a
Sei Whale (northern hemisphere subspecies)	*Balaenoptera b. borealis*	Yes	Endangered	Endangered	Endangered	Cooke, 2018b
Bryde's whale	*Balaenoptera edeni*	Yes	Least Concern	--	--	Cooke and Brownell, 2018
Blue Whale (northern hemisphere subspecies)	*Balaenoptera m. musculus*	Yes	Endangered	Endangered	Endangered	Cooke, 2018c
Fin Whale (northern hemisphere subspecies)	*Balaenoptera p. physalus*	Yes, but some have year-round residency	Vulnerable	Threatened	Special Concern	Cooke, 2018d
Gray Whale	*Eschrichtius robustus*	Yes	Least Concern	Not Listed[4]	Not at Risk[1]	Cooke, 2018e
North Pacific Right Whale	*Eubalaena japonica*	Yes	Endangered	Endangered	Endangered	Cooke and Clapham, 2018
Humpback Whale (North Pacific subspecies)	*Megaptera novaeangliae kuzira*	Yes	Least Concern	Special Concern	Special Concern	Cooke, 2018f

COSEWIC = Committee on the Status of Endangered Wildlife in Canada; IUCN = International Union for the Conservation of Nature; SARA = Species at Risk Act.

Common Minke Whale *(Balaenoptera acutorostrata)*

The common minke whale is a small mysticete that is divided into three subspecies. The subspecies *B. a. scammoni* occurs within the North Pacific (Committee on Taxonomy, 2017). Adult common minke whales reach a length of up to 10.7 m (35 ft) (Jefferson et al., 2008).

[4] Northern Pacific Migratory Population.

Distribution

The minke whale has a cosmopolitan distribution and occurs in polar, temperate, and tropical waters. In the Pacific, minke whales are usually seen over continental shelves (Brueggeman et al., 1990). The distribution of common minke whales in the northern Pacific Ocean within the extreme northern part of their range are believed to be migratory, but within the inland waters of Washington and in central California, they appear to establish home ranges (Dorsey et al., 1990). Although minke whales are relatively common within their northern range (Bering and Chukchi seas and in the Gulf of Alaska), they are not considered abundant in any other part of the eastern Pacific (Leatherwood et al., 1982; Brueggeman et al., 1990).

Auditory and Vocalization Range

Minke whale vocalizations are low-frequency, ranging from 80 Hz to 20 kHz range (Winn and Perkins, 1976; Frankel, 2002). They are classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007, 2019).

Status

Minke whales off the coasts of Washington, Oregon, and California are included within the California/Oregon/Washington stock. Minke whales are not listed under SARA and are listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies minke whales as a species of **Least Concern**.

Sei Whale *(Balaenoptera borealis)*

The sei whale is a large mysticete that is divided into two subspecies. The subspecies *B. b. borealis* occurs within the northern hemisphere (Committee on Taxonomy, 2017). Adult sei whales reach length of 12 to 18 m (40 to 60 ft) (Jefferson et al., 2008).

Distribution

Sei whales have a cosmopolitan distribution and occur in subtropical, temperate, and subpolar waters around the world but appear to prefer temperate waters in the mid-latitudes. The entire distribution and movement patterns of this species is not well known. Sei whales are distributed in oceanic waters and do not appear to be associated with coastal features. This species may unpredictably and randomly occur in a specific area, sometimes in large numbers. Sei whales' summer distribution is known to be mainly north of 40° N latitude. While little is known about the species' winter distribution (Reilly et al., 2008a), animals migrate southward to lower latitudes. There have been no sightings of sei whales off Canada's Pacific coast since the moratorium on commercial whaling in 1976; however, the species prefers deeper offshore habitat more so than other species (Government of Canada, 2021a).

Auditory and Vocalization Range

Recorded vocalizations of sei whales range from 432 Hz to 3.5 kHz (Thompson et al., 1979; Knowlton et al., 1991; McDonald et al., 2005). While there are no direct hearing data available for this species (Ketten, 2000), sei whales are classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007, 2019).

Status

Sei whales are listed as **Endangered** under SARA and by COSEWIC. The IUCN Red List also classifies Sei whales as **Endangered**.

Bryde’s Whale *(Balaenoptera edeni)*

The IUCN regards the Bryde's whale as a species whose taxonomy is "not yet settled"; there are at least two and maybe three Bryde's whale species (Reilly et al., 2008b). Currently, there are two recognized subspecies. The subspecies *B. e. brydei* occurs within the North Pacific (Committee on Taxonomy, 2017). Bryde’s whales can reach lengths of about 13 to 16.5 m (40 to 55 ft).

Distribution

Bryde's whales have a circumglobal distribution in tropical and subtropical waters and are distributed widely across the tropical and warm-temperate Pacific (Leatherwood et al., 1982). Bryde’s whales are not found in Canada’s Pacific waters.

Auditory and Vocalization Range

Bryde’s whale vocalizations are low-frequency, ranging from 20 to 900 Hz (Cummings, 1985; Oleson et al., 2003). The species is classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007, 2019).

Status

Bryde's whales are not listed under SARA and have not been assessed by COSEWIC. The IUCN Red List classifies Bryde’s whales as a **Least Concern** species.

Blue Whale *(Balaenoptera musculus)*

The blue whale is the largest whale species and is divided into five subspecies. The subspecies *B. m. musculus* occurs within the northern hemisphere (Committee on Taxonomy, 2017). North Pacific blue whales were once thought to comprise five separate populations (Reeves et al., 1998). Recent acoustic evidence suggests only two populations, one each in the eastern and western north Pacific, respectively (Stafford et al., 2001; Stafford, 2003; McDonald et al., 2006; Monnahan et al., 2014). Adult blue whales reach a length of up to about 33 m (110 ft) (Jefferson et al., 2008).

Distribution

The blue whale is a cosmopolitan species, found in all oceans except the Arctic and some regional seas such as the Mediterranean, Okhotsk, and Bering Seas (Reilly et al., 2008c). Blue whales commonly occur within offshore waters (Rice, 1998); however, individuals are occasionally sighted in relatively shallow water. In particular, there are a few locations in the world where blue whales are known to migrate through near-coastal, relatively shallow areas (Jefferson et al., 2008). In Canada, blue whales in the north Pacific migrate past Vancouver Island in both the spring and fall seasons. There are no current estimates of the population size offshore Canada, but given the rarity of sightings, the population is likely low (Government of Canada, 2021b).

Auditory and Vocalization Range

Blue whales produce a variety of low-frequency sounds in the 10 to 200 Hz band (Stafford et al., 1998, 1999a,b, 2001; Frankel, 2002). Short sequences of rapid frequency modulated calls below 90 Hz are associated with animals in social groups (Moore and Demister, 1999; Mellinger and Clark, 2003). Most blue whale vocalizations are low-frequency, ranging from 17 to 20 Hz. Sound intensity of blue whale vocalizations is the loudest of any animal (up to 188 dB re 1 µPa) (Sears, 2002).

While there are no direct hearing data available (Ketten, 2000), blue whales are classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007, 2019).

Status

In Canada, the Pacific population of the blue whale is listed as **Endangered** under SARA and by COSEWIC. The IUCN Red List also classifies the blue whale as an **Endangered** species, although they note the worldwide population is increasing.

Fin Whale *(Balaenoptera physalus)*

The fin whale is a large baleen whale species and is divided into three subspecies. The subspecies *B. p. physalus* occurs within the northern hemisphere (Committee on Taxonomy, 2017). Fin whales attain a maximum length of about 22 m (75 ft) in the northern hemisphere.

Distribution

Fin whales have a similar known distribution as sei and blue whales. However, this species is known to be distributed further north than the latter species. The northern hemisphere fin whale likely includes both distinct Pacific and Atlantic subspecies (Archer et al., 2013). Fin whales migrate offshore British Columbia between their winter range offshore California and their summer range in the Arctic. It has been noted that some fin whales spend the summertime offshore British Columbia and can be seen year-round off the central and southern California coast (Reilly et al., 2013). In summer, they occur off the entire coast of western North America from California into the Gulf of Alaska. While there appears to be some migration of fin whales, acoustic data suggests that overall there is no marked seasonality in distribution in the North Pacific (Watkins et al., 2000).

Fin whales occur year-round off south and central California (Reilly et al., 2013), in the Gulf of California (Urbane et al*.,* 2005), and in Hawaiian waters (Angliss and Outlaw, 2005). Fin whales in the Gulf of California constitute a genetically isolated subpopulation (Bérubé et al., 2002). In summer, their distribution extends north up to the region around the Gulf of Alaska and the Okhotsk Sea (Reilly et al., 2013; Angliss and Outlaw, 2005).

Auditory and Vocalization Range

Fin whale vocalizations are low-frequency, generally below 70 Hz but ranging up to 750 Hz (Clark et al., 2002). While there are no direct hearing data available (Ketten, 2000), fin whales are classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007).

Status

The Pacific population of the fin whale is listed as **Threatened** under SARA and as a Species of **Special Concern** by COSEWIC. At the last status review by COSEWIC, the fin whale met the criterion for **Threatened** under A1d (actual but potential levels of exploitation), but the species of **Special Concern** status was retained due to noted abundance of the species in neighboring United States waters (Government of Canada, 2021c). The IUCN Red List classifies the fin whale as a **Vulnerable** species.

Gray Whale *(Eschrichtius robustus)*

The gray whale includes one species, although genetic comparisons indicate there are distinct Eastern North Pacific and Western North Pacific population stocks (LeDuc et al*.,* 2002; Lang et al., 2011; Weller et al., 2013). Gray whales mostly feed on tube-dwelling amphipods and polychaete tube worms on the seabed, but can also prey on crabs, baitfish, crab larvae, amphipods, eggs and larvae, and cephalopods.

Distribution

Most gray whales in the Eastern North Pacific population feed in the Chukchi, Beaufort, and northwestern Bering Seas during summer and fall; however, there is a relatively small number of whales (approximately 200) that summer and feed along the Pacific coast between Kodiak Island, Alaska and northern California (Darling, 1984; Gosho et al., 2011; Calambokidis et al., 2012) and are referred to as the Pacific Coast Feeding Group. During winter, there are three primary wintering lagoons in Baja California, Mexico (Jones, 1990). While gray whales were once more widely distributed, they now only occur in North Pacific and adjacent waters. The northern Pacific migratory population migrates from summer foraging grounds in the Chukchi, Beaufort, and Bering Seas to winter breeding grounds off Baja California, Mexico. Some (presumably a small number) also summer and forage between coastal Vancouver Island and central California.

Auditory and Vocalization Range

Gray whales have a limited call repertoire (six distinct calls) and produce low frequency calls – generally ranging between 100 to 2,000 Hz. They are classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007, 2019).

The gray whale is not listed under SARA or by COSEWIC as numbers are well above mid 20th century populations and are considered stable (Government of Canada, 2021d). The IUCN Red List classifies the gray whale as a species of **Least Concern**.

North Pacific Right Whale *(Eubalaena japonica)*

Right whales are large baleen whales. The North Pacific right whale is the largest of the three right whale species (Jefferson et al., 2008). Adults are generally 13.7 to 16.7 m (45 to 55 ft) in length.

Distribution

North Pacific right whales inhabit waters of the Pacific Ocean, particularly between 20° and 60° N latitude. Few sightings of right whales occur in the central North Pacific and Bering Sea. Sightings have been reported as far south as central Baja California and Hawaii, and as far north as the sub-Arctic waters of the Bering Sea and Sea of Okhotsk in the summer. They are considered vagrant in southwestern Canada (Reilly et al., 2008d). They primarily occur in coastal or shelf waters, although movements over deep waters are known. For much of the year, their distribution is strongly correlated to the distribution of their prey. Two areas within the Gulf of Alaska and within the Bering Sea are designated as critical habitat for the North Pacific right whale (73 Federal Register [*FR*] 19000).

Auditory and Vocalization Range

Morphometric analyses of inner ears from stranded North Atlantic right whales (*Eubalaena glacialis*), a congener to North Pacific right whales, were used for development of a preliminary model of the frequency range of hearing. From these results, the estimated hearing range of right whales is 10 Hz to 22 kHz (Parks et al., 2007). They are classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007).

Status

The North Pacific right whale is listed as **Endangered** under SARA and by COSEWIC (Government of Canada, 2021e). The IUCN Red List classifies the North Pacific right whale as **Endangered**.

Humpback Whale *(Megaptera novaeangliae)*

The humpback whale is a large baleen whale species and is divided into three subspecies. The subspecies *M. novaeangliae kuzira* occurs within the North Pacific Ocean (Committee on Taxonomy, 2017). Humpback whales attain a length of 18 to 22 m (60 to 75 ft) in the northern hemisphere.

Distribution

Humpback whales live in all major oceans from the equator to sub-polar latitudes, including the project area. Nearly all populations undertake seasonal migrations between tropical and sub-tropical winter calving and breeding grounds and high-latitude summer feeding grounds.

Humpback whales are a cosmopolitan species (Clapham and Mead, 1999). In the North Pacific, humpback whales migrate from high latitude summer grounds to low latitude winter grounds where they breed (Clapham, 2002). Calving and mating generally occur in coastal waters. In summer, humpback whales range in their distribution from southern California to the roughly the region around Alaska, the Bering Sea, and over to northeastern Japan. In winter, these humpback whales occur off islands from Hawaii to the northern Philippines and off the coast of Mexico and Central America. Canadian waters, especially productive waters offshore British Columbia, are largely used for feeding and as migration routes to far northern feeding areas (Government of Canada, 2021f).

Auditory and Vocalization Range

Humpback songs are known to range from at least 20 Hz to at least 8 kHz. This species is classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz) (Southall et al., 2007, 2019).

Status

Currently, the humpback whale is listed as **Species of Special Concern** under SARA and by COSEWIC. The IUCN Red List classifies the humpback whale as a species of **Least Concern**.

Toothed (Odontocete) Whales, Dolphins, and Porpoises

Twenty-five species of toothed (odontocete) whales and dolphins are known to occur in the waters of the North Pacific Ocean (**Table 4-10**). These include one species (sperm whale) classified as **Vulnerable** under the IUCN Red List. All other odontocete species are listed as **Least Concern** or **Data Deficient** under the IUCN Red List.

Vocalization information for specific odontocetes and/or odontocete groups are presented in Erbe et al. (2017) and Southall et al. (2019). Given the lack of **Endangered** species likely to be encountered in the NPSG and the limited auditory impacts associated with deployment of S002, no further species-specific information is presented here.

Table 4-10. Toothed whales (Suborder Odontoceti) present between the southwestern Canadian coast and the North Pacific Ocean.

Scientific Name	Common Name	IUCN Red List Status	SARA Status	COSEWIC Status	Reference
Berardius bairdii	Baird's beaked whale	Least Concern	Not Listed	Not at Risk	Taylor and Brownwell, 2020
Delphinus capensis	Long-beaked common dolphin	Data deficient	--	--	Hammond et al., 2008a
Delphinus delphis	Short-beaked common dolphin	Least Concern	Not Listed	Not at Risk	Hammond et al., 2008b
Feresa attenuata	Pygmy killer whale	Least Concern	--	--	Braulik, 2018
Globicephala macrorhynchus	Short-finned pilot whale	Least Concern	Not Listed	Not at Risk	Minton et al., 2018
Grampus griseus	Risso's dolphin	Least Concern	Not Listed	Not at Risk	Kiszka and Braulik, 2018a
Kogia breviceps	Pygmy sperm whale	Least Concern	Not Listed	Not at Risk	Kiszka and Braulik, 2020a
Kogia sima	Dwarf sperm whale	Least Concern	Not Listed	Data Deficient	Kiszka and Braulik, 2020b
Lagenorhynchus obliquidens	Pacific white-sided dolphin	Least Concern	Not Listed	Not at Risk	Ashe and Braulik, 2018
Lissodelphis borealis	Northern-right whale dolphin	Least Concern	Not Listed	Not at Risk	Braulik and Jefferson, 2018
Mesoplodon carlhubbsi	Hubbs' beaked whale	Data deficient	Not Listed	Not at Risk	Pitman and Brownell, 2020a
Mesoplodon densirostris	Blainville's beaked whale	Least Concern	Not Listed	Not at Risk	Pitman and Brownell, 2020b
Mesoplodon ginkgodens	Gingko-toothed beaked whale	Data Deficient	--	--	Pitman and Brownell, 2020c
Indopacetus pacificus	Indo-Pacific beaked whale, or Longman's beaked whale	Least Concern	--	--	Pitman and Brownell, 2020d
Orcinus orca	Killer whale, or Orca	Data Deficient			Reeves et al., 2017
Phocoena phocoena	Harbor porpoise	Least Concern	Special Concern	Special Concern	Braulik et al., 2020
Phocoenoides dalli	Dall's porpoise	Least Concern	Not Listed	Not at Risk	Jefferson and Braulik, 2018
Physeter macrocephalus	Sperm whale	Vulnerable	Not Listed	Not at Risk	Taylor et al., 2019
Pseudorca crassidens	False killer whale	Near Threatened	Not Listed	Not at Risk	Baird, 2018
Stenella attenuata	Pantropical spotted dolphin	Least Concern	--	--	Kiszka and Braulik, 2018b
Stenella coeruleoalba	Striped dolphin	Least Concern	Not Listed	Not at Risk	Braulik, 2019
Stenella longirostris	Spinner dolphin	Least Concern	--	--	Braulik and Reeves, 2018
Steno bredanensis	Rough-toothed dolphin	Least Concern	--	--	Kiszka et al., 2019
Tursiops truncatus	Common bottlenose dolphin	Least Concern	Not Listed	Not at Risk	Wells et al., 2019
Ziphius cavirostris	Cuvier's beaked whale	Least Concern	Not Listed	Not at Risk	Baird et al., 2020

COSEWIC = Committee on the Status of Endangered Wildlife in Canada; IUCN = International Union for the Conservation of Nature; SARA = Species at Risk Act.

Baird's Beaked Whale *(Berardius bairdii)*

The Baird's beaked whale is the largest member of the beaked whale family (Ziphiidae). Females reach lengths of about 13 m (40 ft) and can weigh approximately 12,000 kg (26,400 lb) (Jefferson et al., 2008). They feed on pelagic fish and gadiform fishes, cephalopods, and crustaceans living near the seabed (Balcomb, 1989; Kasuya, 2002), as well as some pelagic fish, such as mackerel, sardines, and saury. Observations of Baird's beaked whales are rare in Canadian waters (Government of Canada, 2021g).

Distribution

The Baird's beaked whale is distributed in the North Pacific Ocean and adjacent seas. They are known to occur from the southern range of the Gulf of California to Honshu (Japan); however, the limits of their range in oceanic waters are not well known (Balcomb, 1989; Kasuya, 2002). There are an estimated 1,100 Baird's beaked whales in the eastern North Pacific, and no information on trends for the species. Baird's beaked whales occur in deep oceanic waters, and sometimes in waters closer to shore where deep water occurs near the coast. Baird's beaked whales have generally been sighted near the continental slope and oceanic seamounts (Kasuya, 2002) at depths of 1,000 to 3,000 m (3,281 to 9,843 ft).

Status

Currently, the Baird's beaked whale is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies the North Pacific right whale as a **Least Concern** species.

Long-beaked Common Dolphin *(Delphinus capensis)*

Long-beaked common dolphins are relatively small dolphins that may reach lengths of 1.9 to 2.6 m (6 to 8.5 ft) and may weigh between 80 and 235 kg (160 and 500 lb) (Jefferson et al., 2008). They are commonly found within about 93 km (50 nmi) of the coast, primarily inshore of the 250-m (820-ft) isobaths, with very few sightings (<15%) in waters deeper than 500 m (1,640 ft) (Carretta et al., 2017).

Distribution

The distribution of long-beaked common dolphins is not well known in many locations. Generally, this species, if found, is observed in nearshore waters (Heyning and Perrin, 1994). Prior to 2005, long-beaked common dolphins were only known from British Columbia from a single stranding. However, Ford (2005) described specimen records and sightings from 1993 to 2005 and concluded the species may be found in Canadian Pacific waters during warm-water periods.

Status

Currently, the long-beaked common dolphin is sufficiently rare in Canadian waters that it has not been assessed under SARA or by COSEWIC. The IUCN Red List classifies the long-beaked common dolphin as a **Data Deficient** species.

Short-beaked Common Dolphin *(Delphinus delphis)*

The short-beaked common dolphin is a small dolphin that may reach approximately 2.7 m (9 ft) in length and may weigh about 200 kg (440 lb) (Jefferson et al., 2008). They prefer oceanic and offshore waters that are warm tropical to cool temperate (10 to 28 °C or 52 to 88°F). They also prefer waters altered by underwater geologic features where upwelling occurs (Hammond et al., 2008b).

Distribution

The short-beaked common dolphin is widely distributed in tropical and temperate waters, including within the Pacific Ocean (Perrin, 2002). Almost 3 million individuals have been estimated for the eastern tropical Pacific and around 352,000 individuals for the U.S. west coast (Gerrodette and Forcada, 2002). This species occurs in offshore and near coastal waters. In some locations, common dolphins show seasonal changes in abundance (Forney and Barlow, 1998). Short-beaked common dolphins in the eastern tropical Pacific have been sighted in association with yellowfin tuna; they prey on schooling fish and squid (Perrin, 2002) and have been found to interact with tuna purse-seine fishing operations (Gerrodette, 2002). They often forage in upwelling areas with steep sea floor gradients (Reilly, 1990; Fiedler and Reilly, 1994). This species is only an occasional visitor to Pacific Canadian waters (Government of Canada, 2021h).

Status

Currently, the short-beaked common dolphin is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies the long-beaked common dolphin as a species of **Least Concern**.

Pygmy Killer Whale *(Feresa attenuata)*

The pygmy killer whale is a small member of the dolphin group. They can reach a length of 2.6 m (8.5 ft) and may weigh up to 170 kg (380 lb) (Jefferson et al., 2008). The pygmy killer whales forage on fish and squid (Perryman and Foster, 1980). However, little additional information is known about their diet.

Distribution

The pygmy killer whale occurs in tropical and subtropical offshore oceanic waters around the world, and close to the coast where there are deep waters. There appears to be uncommon with 38,900 individuals of this species estimated in the eastern tropical Pacific (Wade and Gerrodette, 1993). The pygmy killer whale is not known from Canada.

Status

The pygmy killer whale has not been assessed under SARA or by COSEWIC. The IUCN Red List classifies it as a **Least Concern** species.

Short-finned Pilot Whale *(Globicephala macrorhynchus)*

The short-finned pilot whale is a larger member of the dolphin group reaching average lengths of 5.5 m (18 ft) and weighing 1,000 to 3,000 kg (2,200 to 6,600 lb) (Jefferson et al., 2008). The species is thought to mainly target squid, but is also known to take fish in deep waters over the outer continental shelf or continental slope.

Distribution

Short-finned pilot whales are distributed in warm temperate to tropical waters around the world. The species generally has been sighted in deep offshore waters (Reilly and Shane, 1986; Olson and Reilly, 2002). The estimated abundance of the species in the eastern tropical Pacific is around 590,000 individuals (Gerrodette and Forcada, 2002); off the west coast of North America approximately 300 individuals are estimated, and off Hawaiian waters an estimate of around 8,800 individuals is noted (Barlow, 2006). The species is not common in the Canadian Pacific Ocean (Government of Canada, 2021i).

Status

Currently, the short-finned pilot whale is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies the short-finned pilot whale as a **Least Concern** species.

<u>Risso's Dolphin *(Grampus griseus)*</u>

The Risso's dolphin is a medium-sized cetacean that can reach lengths of approximately 2.6 to 4 m (8.5 to 13 ft) and weigh 300 to 500 kg (660 to 1,100 lb). It is found in temperate, subtropical and tropical waters of 10 to 30°C (50 to 86°F) with depths generally greater than 1,000 m (3,300 ft) (Jefferson et al., 2008). Prey targeted by Risso's dolphin include squid and crustaceans.

Distribution

Risso's dolphins are widely distributed from the tropical to temperate waters (Kruse et al., 1999). The species occurs mostly in deep waters of the continental slope, outer shelf, and in oceanic areas beyond the shelf slope in the eastern tropical Pacific. Among many other locations, it also occurs in the Gulf of California. Abundance estimates of populations off the Pacific northwest of North America has been estimated at approximately 16,000 individuals (Barlow, 2003). Risso's dolphins are rare in Canadian waters (Government of Canada, 2021j). In Hawaiian waters, estimates are around 2,000 individuals. In the eastern tropical Pacific, around 175,000 animals have been estimated (Wade and Gerrodette, 1993).

Status

Currently, Risso's dolphin is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies the Risso's dolphin as a species of **Least Concern**.

<u>Pygmy Sperm Whale *(Kogia breviceps)*</u>

The pygmy sperm whale is a small cetacean that may reach lengths of up to about 3.5 m (11.5 ft) and weigh between 315 and 450 kg (700 and 1,000 lb) (Jefferson et al., 2008). It prefers tropical, subtropical, and temperate waters in oceans and seas worldwide. They are most common along the waters seaward of the continental shelf edge and slope; in most areas, pygmy sperm whales are thought to be more "oceanic" and "anti-tropical" than dwarf sperm whales, the latter of which are discussed below (Jefferson et al., 2008). Pygmy sperm whales are known to feed on cephalopods, deep sea fishes, and shrimp (Aguiar-Dos Santos and Haimovici, 2001; McAlpine et al., 1997).

Distribution

Pygmy sperm whales are distributed in all tropical to warm temperate oceans (McAlpine, 2002). The species' range is poorly known, and no global abundance estimates available, however estimates off California, Oregon, and Washington are around 250 individuals (Barlow, 2003). Estimates off Hawaii are higher, around 7,000 individuals (Barlow, 2006). Pygmy sperm whales are uncommon in Canadian waters.

Status

Currently, the pygmy sperm whale is not listed under SARA and listed as **Not at Risk** by COSEWIC The IUCN Red List classifies the pygmy sperm whale as a **Least Concern** species.

<u>Dwarf Sperm Whale *(Kogia sima)*</u>

The dwarf sperm whale is a small cetacean that can reach lengths of up to about 2.7 m (9 ft) and weigh between 135 and 270 kg (300 and 600 lb). It prefers warm tropical, subtropical, and temperate waters worldwide, and is most common along the waters of the continental shelf edge and slope. Dwarf sperm whales are thought to occur in shallower depths than pygmy sperm whales

(Jefferson et al., 2008). Like pygmy sperm whales, dwarf sperm whales appear to feed on cephalopods in deep water, among other prey species (Aguiar-Dos Santos and Haimovici, 2001).

Distribution

The dwarf sperm whale appears to be distributed widely in offshore waters of tropical and warm temperate areas (Caldwell and Caldwell, 1989). Like the pygmy sperm whale, no global estimates of the population are available. Off Hawaii, estimates are around 19,000 individuals, and in the eastern tropical Pacific around 11,200 animals (Wade and Gerrodette, 1993). Off Hawaii, site fidelity has been recorded (Baird et al., 2006). The presence of dwarf sperm whales in Canada's waters is unknown.

Status

Currently, the dwarf sperm whale is not listed under SARA and listed as **Data Deficient** by COSEWIC The IUCN Red List classifies the dwarf sperm whale as a **Least Concern** species.

Pacific White-sided Dolphin *(Lagenorhynchus obliquidens)*

The Pacific white-sided dolphin reaches a length of 1.7 to 2.5 m (5.5 to 8.0 ft) and may weigh between 135 and 180 kg (300 and 400 lb). They are extremely playful and highly social animals. Schools of thousands of Pacific white-sided dolphins are occasionally observed, but group size generally ranges from 10 to 100 animals. They inhabit waters from the continental shelf to the deep open ocean (Jefferson et al., 2008). The species feed on cephalopods and small pelagic schooling fish such as lanternfish, anchovies, saury, horse mackerel, and hake (Brownell et al., 1999).

Distribution

Pacific white-sided dolphins occur in temperate waters of the North Pacific and adjacent seas (Brownell et al., 1999; Van Waerebeek and Würsig, 2002). In the central North Pacific, abundance estimates range from 900,000 to 1 million (Buckland et al., 1993; Miyashita, 1993a), however these are considered to likely be overestimated (Buckland et al., 1993). Abundance estimates off the U.S. west coast are between 13,000 and 122,000 individuals (Forney et al., 1995). Pacific white-sided dolphins occur in shelf and slope waters of continental margins (Carretta et al., 2006), and in some inland waterways such as off British Columbia (Heise, 1997). The species is an abundant, permanent resident of pelagic waters off the west coast of Canada (Government of Canada, 2021k).

Status

Currently, the Pacific white-sided dolphin is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies the dwarf sperm whale as a species of **Least Concern**.

Northern Right Whale Dolphin *(Lissodelphis borealis)*

The northern right whale dolphin may reach lengths of approximately 2 to 3 m (6.5 to 10 ft) and may weigh between 60 and 115 kg (130 and 250 lb). They are generally found in waters over the continental shelf and slope that are colder than 19°C (66°F) (Jefferson et al., 2008). Northern right whale dolphins feed on cephalopods and mid-water fishes, among other species (such as market squid and lanternfish off southern California).

Distribution

The northern right whale dolphin has been sighted in the North Pacific Ocean in deep, temperate waters. Estimates of abundance are available for some geographical regions. In the oceanic North Pacific, between 307,000 and 400,000 animals have been estimated (Buckland et al., 1993; Miyashita, 1993a; Hiramatsu, 1993). The distribution in the eastern North Pacific appears to vary seasonally (Forney and Barlow, 1998), though it is rare in Canadian waters (Government of Canada, 2021l). This species occurs in deep oceanic waters off the outer continental shelf, and sometimes closer to the coast in deep water areas (including in the California Current system) (Jefferson et al., 1994).

Status

Currently, the northern right whale dolphin is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies the dwarf sperm whale as a species of **Least Concern**.

Hubb's Beaked Whale *(Mesoplodon carlhubbsi)*

The Hubb's beaked whale is a poorly known species, and few specimens (less than 60 records) have been examined. These specimens were up to 5.32 m in length. The species is oceanic, feeding on squid and deepwater fishes. Currently, there are no abundance estimates available for this species.

Distribution

Hubbs' beaked whale is only known to occur off central British Columbia down to southern California, and off Japan (Mead, 1989; MacLeod et al., 2006), and is thought to occur across the North Pacific (MacLeod et al., 2006). Nothing is known about movements within either parts of their range and species distribution data from the high seas is unavailable.

Status

Currently, the Hubb's beaked whale is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies it as a **Data Deficient** species.

Blainville's Beaked Whale *(Mesoplodon densirostris)*

The Blainville's beaked whale can reach lengths of approximately 4.5 to 6 m (15 to 20 ft) and may weigh 820 to 1,030 kg (1,800 to 2,300 lb). They are generally found in deep, offshore waters of the continental shelf. This species is often associated with steep underwater geologic structures such as banks, submarine canyons, seamounts, and continental slopes (Jefferson et al., 2008). Blainville's beaked whale feeds on squid and deepwater fish (Heyning and Mead, 1996).

Distribution

The distribution of Blainville's beaked whales is considered the most extensive of the *Mesoplodon* genus. They have a cosmopolitan distribution throughout the world's oceans and range from the Mediterranean, England, Iceland, Nova Scotia, Brazil and South Africa in the Atlantic; to California, Chile, Japan, New Zealand and Australia in the Pacific. They appear to be relatively common in tropical waters (Reeves et al., 2003). This species appears to occur mostly in deep offshore waters, but can occur closer to shore in deep waters (MacLeod and Zuur, 2005). They are not regularly known from the west coast of Canada.

Status

Currently, Blainville's beaked whale is not listed under SARA and listed as **Not at Risk** by COSEWIC. The IUCN Red List classifies it as a **Least Concern** species (Pitman and Brownell, 2020b).

Ginkgo-toothed Beaked Whale *(Mesoplodon ginkgodens)*

Ginkgo-toothed beaked whales are more robust than most *Mesoplodon* species, reaching lengths of 4.9 m (16 ft). The species does not appear to be very common anywhere. This species is thought to primarily feed on squid and fish.

Distribution

The ginkgo-toothed beaked whale has been sighted in deep, oceanic temperate and tropical waters of the Indo-Pacific Ocean, among other locations (Mead, 1989; Pitman, 2002), and is thought to occur across the Pacific and into the eastern Indian Ocean (MacLeod et al., 2006). They are not known from coastal Canadian waters.

Status

The ginkgo-toothed beaked whale has not been assessed under SARA or by COSEWIC. The IUCN Red List classifies it as a **Data Deficient** species.

<u>Longman's Beaked Whale *(Indopacetus pacificus)*</u>

The Longman's beaked whale is considered one of the least known cetacean species. Compared to other *Mesoplodon* species, it is relatively large, reaching lengths of about 6 to 9 m (20 to 30 ft). Their weight is unknown (Jefferson et al., 2008). They live in generally warm (21 to 31°C [69.8 to 87.8°F]) and deep (greater than 1,000 m [3,300 ft]) waters. The species appears to primarily feed on cephalopods (Yamada, 2004).

Distribution

Longman's beaked whales do not appear to be common. Sightings have been from the tropical and subtropical Indo-Pacific, with abundance estimates off Hawaii of 1,007 individuals and 291 animals in the eastern North Pacific (Ferguson and Barlow, 2001; Barlow, 2006). They are not known from coastal Canadian waters.

Status

The Longman's beaked whale has not been assessed under SARA or by COSEWIC. The IUCN Red List classifies it as a **Least Concern** species.

<u>Killer Whale *(Orcinus orca)*</u>

The killer whale is a large cetacean, with males reaching up to 10 m (32 ft) in length and 10,000 kg (22,000 lb) in weight. Genetic studies and morphological evidence suggest the existence of multiple species or subspecies of killer whales worldwide. Killer whales are most abundant in colder waters, but may be fairly abundant in temperate waters. Killer whales also occur, though at lower densities, in tropical, subtropical, and offshore waters. Their diet is often geographic or population specific, and may include fishes, marine mammals, and seabirds (Jefferson et al., 2008).

Killer whales within the project area may be members of several populations as defined by Canadian regulators: the Northeast Pacific northern resident population (occurring mainly from Alaska southward to Washington State), Northeast Pacific southern resident population (occurring mainly from northern British Columbia southward to central California), Northeast Pacific offshore population (occurring across the northeast Pacific, but generally further from shore than other populations), or the Northeast Pacific transient population (widely distributed in coastal waters of the eastern North Pacific) (Government of Canada, 2021m).

Distribution

Killer whales are a cosmopolitan species, occurring worldwide (Forney and Wade, 2006). Killer whales tend to be more common along continental margins and in temperate and polar waters than tropical waters. Global abundance estimates have resulted in 50,000 killer whales, however more accurate population-specific estimates have been made. Estimates of killer whales in the eastern tropical Pacific are at around 8,500 animals (Wade and Gerrodette, 1993).

Of the populations found in nearshore Canadian waters, the Northeast Pacific northern resident population has been estimated at 290 individuals (as of 2014); the Northeast Pacific southern resident population has been estimated at 78 individuals (as of 2014); the Northeast Pacific offshore population has been estimated at 300 individuals (as of 2013); and the Northeast Pacific transient population has been estimated at 349 individuals (as of 2019) (Government of Canada, 2021m). Under SARA, critical habitat has been established in the Straits of Georgia and Juan de Fuca for the Northeast Pacific southern resident population (Port of Vancouver, 2020).

Status

Of the populations found in nearshore Canadian waters, the Northeast Pacific northern resident population is classified as **Threatened** under SARA and by COSEWIC; the Northeast Pacific southern resident population is classified as **Endangered** under SARA and by COSEWIC; the Northeast Pacific offshore population is classified as **Threatened** under SARA and by COSEWIC; and the Northeast Pacific transient population is classified as **Threatened** under SARA and by COSEWIC (Government of Canada, 2021m). The IUCN Red List classifies the killer whale (globally) as a **Data Deficient** species.

Harbor Porpoise *(Phocoena phocoena)*

The harbor porpoise is a small cetacean, reaching lengths of 1.5 to 1.7 m (5 to 5.5 ft) and weighing from 61 to 77 kg (135 to 170 lb). They are commonly found in bays, estuaries, harbors, and fjords less than 200 m (650 ft) deep (Jefferson et al., 2008). Harbor porpoises target a wide variety of fish and cephalopods (Smith and Gaskin, 1974; Recchia and Read, 1989; Fontaine et al., 1994; Gonzales et al., 1994; Aarefjord et al., 1995; Gannon et al., 1998; Read, 1999; Börjesson et al., 2003; Santos et al., 2004; Reeves and Notarbartolo di Sciara, 2006).

Distribution

Harbor porpoises occur in cold temperate and sub-polar waters in the northern hemisphere (Gaskin, 1992; Read, 1999) in continental shelf waters and sometimes in deeper offshore waters. In the eastern North Pacific, they range from central California to the Chukchi Sea.

Status

The Pacific Ocean population of the harbor porpoise is listed under SARA and by COSEWIC as a species of **Special Concern**. The IUCN Red List classifies it as a species of **Least Concern**.

Dall’s Porpoise *(Phocoenoides dalli)*

The Dall’s porpoise can reach a maximum length of approximately 2.4 m (8 ft) and may weigh up to 220 kg (480 lb)). They can be found in offshore, inshore, and nearshore oceanic waters (Jefferson et al., 2008). Dall's Porpoise forage on a wide range of fish and squid, among other prey (e.g., krill, shrimps) (Houck and Jefferson, 1999; Jefferson, 2002a).

Distribution

Dall's porpoises occur only in the northern North Pacific Ocean and adjacent seas in deep waters (Jefferson, 1988; Houck and Jefferson, 1999), from the west coast of North America to Japan. Dall’s porpoise occurs in offshore deep waters and in fjords and channels (Miyashita and Kasuya, 1988; Jefferson, 1988; Rice, 1998).

Status

The Dall’s porpoise is not listed under SARA and listed by COSEWIC as **Not at Risk**. The IUCN Red List classifies it as a species of **Least Concern**.

Sperm Whale *(Physeter macrocephalus)*

The sperm whale is a large cetacean, with adult males reaching approximately 16 m (52 ft) and 40,823 kg (45 tons) in weight. Sperm whales commonly inhabit areas with a water depth of 600 m (1,968 ft) or more, and are uncommon in waters less than 300 m (984 ft) deep. Sperm whales forage on cephalopods and fish, among other species (Jefferson et al., 2008).

Distribution

The sperm whale is widely distributed around the world (Rice, 1989). It generally occurs along the continental slope and in deeper waters. Sperm whales are distributed across the entire North Pacific and into the southern Bering Sea in summer, but the majority are thought to be south of 40°N in winter. They are widely found year-round in British Columbia waters. Sperm whale population trend estimates indicate that a pre-whaling global population may have been around 1,100,000 animals and have been reduced by approximately 67% (Whitehead, 2002).

Status

Sperm whales are not listed under SARA and are listed by COSEWIC as **Not at Risk**. The IUCN Red List classifies it as a **Vulnerable** species.

False Killer Whale *(Pseudorca crassidens)*

The false killer whale is a large member of the dolphin family. Males reach lengths of almost 6 m (20 ft) and weigh approximately 700 kg (1,500 lb)). False killer whales mostly occur in relatively deep offshore waters (Stacey et al., 1994; Odell and McClune, 1999), but also occur in some partially enclosed seas and bays. False killer whales mostly forage on fish and cephalopods, but can attack small cetaceans (Baird et al., 2008).

Distribution

False killer whales are found in tropical to warm temperate waters in all oceans. Abundance off Hawaii has been estimated to be 268 animals (Barlow, 2006). In the eastern tropical Pacific, abundance has been estimated at 39,800 individuals (Wade and Gerrodette, 1993). However, no global estimates are available. False killer whales are rare in Canadian waters (Government of Canada, 2021n).

Status

False killer are not listed under SARA and are listed by COSEWIC as **Not at Risk**. The IUCN Red List classifies it as a **Near Threatened** species.

Pantropical Spotted Dolphin *(Stenella attenuata)*

The pantropical spotted dolphin is a relatively small dolphin species, reaching lengths of 2 m (7 ft) and weighing approximately 114 kg (250 lb) at adulthood. They spend the majority of daylight hours in shallower water (usually between 90 to 300 m [300 and 1,000 ft] deep). At night, they dive into deeper waters to search for prey. Pantropical spotted dolphins prey on fish, squid, and crustaceans (Robertson and Chivers, 1997).

Distribution

The pantropical spotted dolphin occurs in all oceans between around 40°N and 40°S. It is more abundant in lower latitudes. In the eastern Pacific, over 220,000 coastal animals were estimated in 2000 (Gerrodette and Forcada, 2002), and offshore in the eastern North Pacific estimates were 737,000 animals in 2003 (CV=15%; Gerrodette et al., 2005), 24% of what they were estimated to be approximately 45 years earlier (Reilly et al., 2005). Within the eastern Pacific, pantropical spotted dolphins occur in greatest numbers in the region north of the Equator (the "Inner Tropical" waters). The species is not known from coastal Canadian waters.

Status

The pantropical spotted dolphin has not been assessed under SARA or by COSEWIC. The IUCN Red List classifies it as a species of **Least Concern**.

Striped Dolphin *(Stenella coeruleoalba)*

The striped dolphin can reach lengths of approximately 2.7 m (9 ft) and may weigh up to 160 kg (350 lb) for males. They prefer highly productive tropical to warm temperate oceanic waters (10 to 26°C or 52 to 84°F) and are often linked to upwelling areas and convergence zones (Jefferson et al., 2008). Striped dolphins forage on a wide variety of fish and squids in continental slope or oceanic regions (Wurtz and Marrale, 1993; Hassani et al., 1997; Archer, 2002).

Distribution

Striped dolphins are widely distributed in tropical and warm temperate oceans and seas. The striped dolphin abundance in the western North Pacific was estimated as 570,000 (Miyashita, 1993b). In the eastern tropical Pacific, population estimates were over 1,400,000 animals (Gerrodette et al., 2005). Off Hawaii, numbers are estimated at above 13,000 individuals (Barlow, 2006). Striped dolphins in the North Pacific occur in oligotrophic waters of the Central North Pacific Gyre and in upwelling areas in the eastern tropical Pacific (Miyazaki et al., 1974; Reilly, 1990; Archer and Perrin, 1999; Balance et al., 2006). Striped dolphins have been observed offshore British Columbia but are rare due to water temperatures which are typically cooler than preferred.

Status

Striped dolphins are not listed under SARA and are listed by COSEWIC as **Not at Risk**. The IUCN Red List classifies it as a species of **Least Concern**.

Spinner Dolphin *(Stenella longirostris)*

The spinner dolphin is relatively small, reaching lengths of 2 m (7 ft) and weighing approximately 59 to 77 kg (130 to 170 lb) at adulthood. In most places, spinner dolphins are found in the deep ocean where they likely track prey (Jefferson et al., 2008). Six morphotypes within four subspecies of spinner dolphins have been described worldwide in tropical and warm-temperate waters (Perrin et al., 2009). The Gray's (or pantropical) spinner dolphin (*Stenella longirostris longirostris*) is the most widely distributed subspecies and is found in the Atlantic, Indian, central and western Pacific Oceans, including the project area (Perrin et al., 1991). Spinner dolphins forage on a variety of fish, squid, and shrimp (Perrin et al., 1973; Dolar et al., 2003).

Distribution

Spinner dolphins occur in tropical and subtropical zones in both hemispheres, mainly around oceanic islands (Rice, 1998). Spinner dolphins occur in pelagic waters over the continental shelf in the eastern tropical Pacific and off Baja California (Perrin, 1990). An abundance estimate of approximately 801,000 individuals present in the Eastern Tropical Pacific was noted in 2000 (Gerrodette et al., 2005). In the Eastern Tropical Pacific, spinner dolphins can occur in very large numbers offshore from the coast. Spinner dolphins do not occur in Canadian waters.

Status

The spinner dolphin has not been assessed under SARA or by COSEWIC. The IUCN Red List classifies it as a **Data Deficient** species.

Rough-toothed Dolphin *(Steno bredanensis)*

The rough-toothed dolphin is a small member of the dolphin group that can grow up to 2.6 m (8.5 ft) long and weigh about 160 kg (350 lb). They prefer deeper areas of tropical and warmer temperate waters where their prey is concentrated (Jefferson et al., 2008). Rough-toothed dolphins feed on cephalopods and fish (Pitman and Stinchcomb, 2002).

Distribution

The rough-toothed dolphin occurs in deep tropical and subtropical waters (Jefferson, 2002b). Around 145,000 rough-toothed dolphins have been estimated to occur in the eastern tropical Pacific (Wade and Gerrodette, 1993), and almost 20,000 individuals may be present off Hawaii (Carretta et al., 2006). The rough-toothed dolphin occurs mainly in waters beyond the continental shelf (Maigret, 1994), but can be seen closer to the coast in deep areas with a steep seabed gradient (Ritter, 2002). Rough-toothed dolphins do not occur in Canadian waters.

Status

The Rough-toothed dolphin has not been assessed under SARA or by COSEWIC. The IUCN Red List classifies it as a species of **Least Concern**.

Common Bottlenose Dolphin *(Tursiops truncatus)*

The common bottlenose dolphin ranges in lengths from 1.8 to 3.8 m (6.0 to 12.5 ft) and may weigh from 136 to 635 kg (300 to 1400 lb). It is found in temperate and tropical waters around the world. There are both coastal populations that inhabit bays, estuaries and river mouths as well as offshore populations that inhabit pelagic waters along the continental shelf and slope. Common bottlenose dolphins prey on a wide range of fish and squid (Barros and Odell, 1990; Barros and Wells, 1998; Blanco et al., 2001; Santos et al., 2001), and can prey on shrimp and other crustaceans.

Distribution

Common bottlenose dolphins are distributed worldwide in tropical and temperate waters. This species occurs inshore, shelf, and oceanic waters (Leatherwood and Reeves, 1990; Wells and Scott, 1999; Reynolds et al., 2000). A minimum global abundance estimate may be on the order of 600,000 animals. In the east tropical Pacific, around 240,000 common bottlenose dolphins have been estimated (Wade and Gerrodette, 1993); off Hawaii, abundance estimates exceed 3,000 animals (Barlow, 2006), while in inshore waters off California around 300 animals are estimated (Dudzik et al., 2006). Offshore California, Oregon, and Washington around 2,000 animals have been estimated (Bearzi et al., 2012). Common bottlenose dolphins are occasional visitors to British Columbia waters, but are not common (Government of Canada, 2021o).

Status

Common bottlenose dolphins are not listed under SARA and are listed by COSEWIC as **Not at Risk**. The IUCN Red List classifies it as a species of **Least Concern**.

Cuvier's Beaked Whale *(Ziphius cavirostris)*

The Cuvier's beaked whale can reach lengths of about 4.5 to 7 m (15 to 23 ft) and weigh 1,845 to 3,090 kg (4,000 to 6,800 lb). It may be found in temperate, subtropical, and tropical waters of the continental slope and edge (usually where water depth is greater than 1,000 m [3,300 ft]), as well as around steep underwater geologic features like banks, seamounts, and submarine canyons. It feeds mostly on squid, fish, and crustaceans (MacLeod et al., 2003). Cuvier's beaked whales that occur within the project area are members of the California/Oregon/Washington management stock.

Distribution

Cuvier's beaked whales are distributed in offshore waters from tropical waters to polar regions in both hemispheres (Heyning, 1989, 2002), and in some enclosed seas such as the Gulf of California. Cuvier's beaked whales appear to be common with a possible worldwide abundance around 100,000 animals. In the eastern tropical Pacific, abundance estimated have been around 80,000 animals (Ferguson and Barlow, 2001). Off the United States west coast, estimated abundance was around 1,800 individuals (Barlow, 2003). Off Hawaii, abundance estimates were around 15,000 animals (Barlow, 2006). Cuvier's beaked whales are only rarely found in Canadian waters (Government of Canada, 2021p).

Status

Cuvier's beaked whales are not listed under SARA and are listed by COSEWIC as **Not at Risk**. The IUCN Red List classifies it as a species of **Least Concern**.

4.3.4.2 Seals and Sea Lions

The suborder Pinnipedia includes seals, sea lions, and walruses. Four eared seals (Family Otariidae) and two true seals (Family Phocidae) are known to occur in the waters between the west coast of Canada and the deployment area in the NPSG. These include four species classified by the IUCN as **Least Concern** (Guadalupe fur seal, California sea lion, Northern elephant seal, and Pacific Harbor seal), one **Vulnerable** (northern fur seal)**,** and one **Near Threatened** (Steller sea lion) (**Table 4-11**).

Seals and sea lions have specific core areas of distribution, however vagrants are commonly sighted outside of these core areas. Two species are listed as migratory, including the Northern fur seal and the Northern elephant seal. Migratory species generally migrate during particular seasons or life stages.

Vocalization information for specific pinnipeds and/or pinniped groups are presented in Erbe et al. (2017) and Southall et al. (2019). Given pinnipeds will likely only be encountered during vessel transit, the lack of **Endangered** species likely to be contacted, and the limited auditory impacts associated with vessel transit, no further species-specific vocalization information is presented here.

Table 4-11. Seals and sea lions present from the southwestern Canadian coast to the offshore area of the North Pacific Subtropical Gyre.

Scientific Name	Common Name	Migratory	IUCN Red List Status	SARA Status	COSEWIC Status	Reference
Arctocephalus townsendi	Guadalupe fur seal	No	Least concern	--	--	Aurioles-Gamboa, 2015
Callorhinus ursinus	Northern fur seal	Yes	Vulnerable	Not Listed	Threatened	Gelatt et al., 2015
Eumetopias jubatus jubatus	Steller sea lion	No	Near Threatened	Special Concern	Special Concern	Committee on Taxonomy, 2017; Gelatt and Sweeney, 2016
Zalophus californianus	California sea lion	Yes	Least Concern	Not Listed	Not at Risk	Aurioles-Gamboa and Hernández-Camacho, 2015
Mirounga angustirostris	Northern elephant seal	Yes	Least Concern	Not Listed	Not at Risk	Hückstädt, 2015
Phoca vitulina richardii	Pacific harbor seal	No	Least Concern	Not Listed	Not at Risk	Harvey, 2016

COSEWIC = Committee on the Status of Endangered Wildlife in Canada; IUCN = International Union for the Conservation of Nature; SARA = Species at Risk Act. -- = not assessed.

Steller Sea Lion *(Eumetopias jubatus)*

The Steller sea lion is the largest otariid seal, with adult males reaching a length of about 3.3 m (11 ft) and average weight of 1,000 kg (2,205 lb) (Jefferson et al., 2008).

Distribution

The Steller sea lion is distributed as far south as central California north to the Gulf of Alaska, through the Aleutian Islands, the Kamchatka Peninsula, across to the Japan and the Sea of Japan (Loughlin, 2009). Vagrants have been reported in China and Herschel Island (Rice, 1998).

Core habitat used by Steller sea lions mainly includes coastal and continental shelf waters. However, Steller sea lions occur in deep ocean waters in some areas. Offshore waters are accessed during regular foraging trips where adult sea lions target pelagic fish and invertebrates and may dive to over 400 m (1,312 ft) in depth (Merrick and Loughlin, 1997; Fadely and Lander, 2012; Fadely et al., 2013; Gelatt and Sweeny, 2016). Steller sea lions can often be found in high numbers in areas of high prey concentrations and around fishing vessels (Gelatt and Sweeny, 2016). Steller sea lions breed in late spring and summer, with pupping occurring between May and July. During the non-breeding season (winter) females may engage in longer foraging trips (Merrick and Loughlin, 1997; Fadely and Lander, 2012; Fadely et al., 2013). In Canadian waters, there are three main breeding areas: Scott Island (just off northern Vancouver Island), Cape St. James (just off the southern Queen Charlotte Islands), and the Banks Islands. There are also numerous well-known haul out sites in the coastal areas of British Columbia (Government of Canada, 2021q)

Status

The Steller sea lion is listed by SARA and under COSEWIC as a species of **Special Concern** due to its restricted breeding range and sensitivity to human disturbance while on land. The species is classified as **Near Threatened** by the IUCN.

Northern Fur Seal *(Callorhinus ursinus)*

The northern fur seal is an otariid seal that may attain lengths of 2.1 m (7 ft) and a weight of 270 kg (595 lb). They primarily use two types of habitat, including open ocean for foraging and rocky beaches for reproduction (NMFS, 2017).

Adult fur seals spend over 300 days per year foraging at sea, and often concentrate around major oceanographic features such as seamounts, canyons, valleys, and along the continental shelf break, based on the availability of prey. Breeding seals normally haul-out on rocky beaches, but colonies can also use broad sandy beaches.

Distribution

The northern fur seal is distributed between the Bering Sea and California (Sterling et al., 2014), including areas offshore British Columbia. These seals spend most time during non-breeding periods in pelagic waters foraging in offshore areas and the edge of the continental shelf. Many migrate between the Bering Sea and California during non-breeding periods. During the breeding season, around June to August, northern fur seals spend around 1 to 1.5 months on land. Most of the northern fur seals found in Canadian waters breed either in Alaska or in California (Government of Canada, 2021r).

Status

The northern fur seal is not listed by SARA (review is pending for addition) and under COSEWIC as **Threatened.** The IUCN classifies the species as **Vulnerable**.

Guadalupe Fur Seal *(Arctocephalus townsendi)*

The Guadalupe fur seal is an otariid seal that may attain lengths of 2 m (7 ft) and a weight of 160 to 170 kg (353 to 375 lb) (Jefferson et al., 2008). They primarily use two types of habitat, including open ocean for foraging and rocky beaches for reproduction (NMFS, 2017). Guadalupe fur seals are solitary, non-social animals.

Distribution

Guadalupe fur seals are distributed mainly on islands along the coast of California, with vagrants reported as far as Washington State (Moss et al., 2006). Little is known about the breadth of their foraging activities and offshore distribution when at sea. However, evidence indicates that Guadalupe fur seals forage as far off the coast as several hundred kilometers. The breeding season is in summer, with the greatest number of pups being born on Guadalupe Island (around June; Wickens and York, 1997; Aurioles-Gamboa, 2015). Guadalupe fur seals are not found in Canadian waters.

Status

The Guadalupe fur seal has not been assessed under SARA or by COSEWIC. The IUCN classifies the species as **Least Concern** (Aurioles-Gamboa, 2015).

California Sea Lion *(Zalophus californianus)*

The California sea lion is an otariid seal that may attain lengths of 2.4 m (8 ft) and a weight of greater than 390 kg (860 lb) (Jefferson et al., 2008). California sea lions occur in shallow coastal and estuarine waters. Sandy beaches are preferred for haul out sites.

Distribution

California sea lions are distributed from the coast of Baja California to the Gulf of Alaska and the Aleutian Islands (Maniscalco et al., 2004; Aurioles-Gamboa and Hernández-Camacho, 2015). These sea lions forage on the continental shelf and slopes on fish and cephalopods on the benthos as well as within the pelagic region of the water column (García-Rodríguez and Aurioles-Gamboa, 2004; Weise et al., 2010; Villegas-Amtmann et al., 2011). Pups are born in the northern summer between May and July (García-Aguilar and Aurioles-Gamboa, 2003). In Canada, males occasionally migrate from California, but no breeding is known to occur (Government of Canada, 2021s).

Status

The California sea lion is not listed under SARA and is listed by COSEWIC as **Not at Risk**. The IUCN classifies the species as **Least Concern**.

Northern Elephant Seal *(Mirounga angustirostris)*

The northern elephant seal is the largest phocid seal in the northern hemisphere. Males can reach lengths of over 4 m (13 ft) and can weigh nearly 2,000 kg (4,400 lb). They spend about 9 months each year in the ocean (NMFS, 2017).

Distribution

Northern elephant seals are distributed throughout a large area of the eastern Pacific Ocean, from Baja California north of 27° latitude to the Gulf of Alaska and the Aleutian Islands (Le Boeuf et al., 2000; Robinson et al., 2012). Vagrants have been reported from the Midway Islands and Japan. Northern elephant seals forage as far offshore as 8,000 km (4,320 nmi) and can dive to depths greater than 1,700 m (5,577 ft) (Robinson et al., 2012). Pups are born on islands offshore of Baja California and California, with some born as far north as British Columbia (Lowry et al., 2014).

Status

The northern elephant seal is not listed under SARA and is listed by COSEWIC as **Not at Risk**. The IUCN classifies the species as **Least Concern**.

<u>Harbor Seal *(Phoca vitulina richardii)*</u>

The harbor seal is a phocid seal that may reach lengths of 1.9 m (6.2 ft) and weigh 70 to 150 kg (154 to 330 lb) (Jefferson et al., 2008). Two subspecies of the harbor seal exist in the Pacific: *P. v. stejnegeri* in the western North Pacific, near Japan, and *P. v. richardii* in the eastern North Pacific (Carretta et al., 2017). Harbor seals live in temperate coastal habitats and use rocks, reefs, beach, and drifting glacial ice as haul out and pupping sites.

Distribution

Pacific harbor seals are distributed from temperate to polar regions in the North Pacific. Eastern Pacific harbor seals range from Baja California to the Aleutian Islands (Rice, 1998). These seals forage on a range of species of fish, cephalopods, and crustaceans in bays and estuaries, and coastal waters out to the continental shelf slope (Pitcher, 1980; Olesiuk et al., 1990; Lowry, 2016).

Status

The Pacific harbor seal is not listed under SARA and is listed by COSEWIC as **Not at Risk**. The IUCN classifies the species as **Least Concern**.

4.3.5 Sea Turtles

Five species of sea turtles may occur in the NPSG close to where S002 will be deployed (**Table 4-12**). Globally, each of these five species of turtles are all categorized as **Vulnerable**, **Endangered**, or **Critically Endangered** by the IUCN. All marine turtles that occur in the North Pacific are part of a specific subpopulation as defined by the IUCN (**Table 4-9**). These subpopulations differ genetically from other populations but also show different trends in occurrence and have separate status designations on the IUCN Red List.

During transit to the NPSG for deployment of The Ocean Cleanup's System 001 in the NPSG in 2018, one unidentified turtle was observed (Seiche, 2019). During deployment of The Ocean Cleanup's System 001B in the NPSG in 2019, two seas turtles (one green turtle and one loggerhead turtle) were observed in the vicinity of System 001B (**Image 4-4**) (The Ocean Cleanup, 2020). No sea turtles were observed during transit to or from Vancouver.

Image 4-4. A loggerhead sea turtle swimming near the surface in the vicinity of The Ocean Cleanup's System 001B in the North Pacific Subtropical Gyre in 2019. From: The Ocean Cleanup, 2020.

Table 4-12. Sea turtle species in the Pacific Ocean.

Common Name	Scientific Name	Population	Habitat and Diet	IUCN Red List Status for the Global Population and (Regional Subpopulation)
Loggerhead sea turtle	*Caretta caretta*	North Pacific Subpopulation	Occupies three different habitats – oceanic, neritic, and terrestrial (nesting only), depending upon life stage; omnivorous.	Vulnerable (Least Concern)
Olive ridley sea turtle	*Lepidochelys olivacea*	Pacific Subpopulation	Primarily pelagic, but may inhabit coastal areas, including bays and estuaries; most breed annually, with annual migration (pelagic foraging, to coastal breeding/nesting grounds, back to pelagic foraging); omnivorous, benthic feeder. Also forages in the midwater column and on surface-dwelling organisms.	Vulnerable (Vulnerable)
Leatherback sea turtle	*Dermochelys coriacea*	West Pacific Subpopulations	Pelagic, living in the open ocean and occasionally entering shallower water (bays, estuaries); omnivorous (jellyfish; other invertebrates, vertebrates, kelp, algae).	Vulnerable (Critically Endangered)
Green sea turtle	*Chelonia mydas*	Hawaiian and East Pacific subpopulations	Aquatic, but known to bask onshore; juvenile distribution unknown; omnivorous.	Endangered (Least Concern)
Hawksbill sea turtle	*Eretmochelys imbricata*	Indo-Pacific/East Pacific subpopulation	Pelagic; feeding changes from pelagic surface feeding to benthic, reef-associated feeding mode; opportunistic diet.	Critically Endangered (Critically Endangered)

Extensive research is performed on bycatch of turtles (Wallace et al., 2013). Loggerheads, leatherbacks, and green turtles are especially susceptible to impacts from bycatch during fishery activities. While exact numbers on entanglement by discarded fishing gear (e.g., ghost nets, marine debris) are not available, a report by the NOAA Marine Debris Program (NOAA, 2014a) suggests that the percentage of entanglements of all sea turtles as 5%, and Macfadyen et al. (2009) suggests that the threat to marine turtles posed by fishing debris is comparable to the threat posed by active fishing efforts prior to the introduction of turtle exclusion devices. A study by Wilcox et al. (2015) estimated that the total number of turtles caught by the 8,690 ghost nets they sampled was between 4,866 and 14,600 animals, assuming nets drift for one year. Research considered plastic ingestion, a phenomenon widely observed in all marine turtles. It is known that all turtle species interact with marine plastic, with ingestion and entanglement being the two main types of interaction (Gall and Thompson, 2015).

4.3.5.1 Migration and Nesting

Many marine turtle species have their nesting season starting around June through October/November, but nesting season varies by species and populations. During nesting, the species are found close to the nesting areas or are migrating back to these areas. In non-nesting season, marine turtles are migrating and can be found in their migration area (**Table 4-13**). **Table 4-13** shows that all presented sea turtles may occur within the project area.

Table 4-13. Sea turtle species, their nesting and foraging areas, and feeding behavior for turtles found in the North Pacific Ocean (NOAA 2014b,c, 2016a,b, 2017a).

Common Name	Primary Pacific Ocean Nesting Area	Nesting Season	Foraging/Migration Area	Feeding Behavior
Loggerhead sea turtle	Japanese Coast	June to November	North Pacific to Baja California.	Carnivorous, juveniles are omnivorous. Feed on bottom dwelling invertebrates such as horseshoe crabs, clams, mussels, and other invertebrates. During migration, they feed on floating mollusks, jellyfish, sponges, and flying fish.
Olive ridley sea turtle	Mexican west Coast	Typically June to November; extends to January in some locations	Along the west coast from Mexico to as far as Oregon. Within 1,931 km (1,043 nmi) offshore but spotted in the center of the subtropical gyre (140°W).	Omnivorous, shallow prey feeders (crabs, jellyfish, eggs, mollusks).
Leatherback sea turtle	Coast of Indonesia, Papua, Solomon Islands	June to November	Indonesia to California, Mexico.	Gelatinivorous, only soft animals like jellyfish. Deep diving species.
Green sea turtle	Mexico, Hawaii, South Pacific islands	November to April for Mexico populations; June to October for others.	Pacific areas with seagrass.	Herbivorous (sea grass, algae).
Hawksbill sea turtle	Hawaii and Pacific Islands	June to October	Tropical, found in mainly in areas with coral reefs. Migration area extends to the North Pacific.	Spongivorous (preferably sponges and animals in coral reefs).

4.3.5.2 Loggerhead Sea Turtles

Adult loggerhead sea turtles are primarily found in tropical and subtropical coastal waters, but they may be found in the open ocean during migration. Satellite tracking and modeling studies have shown that juvenile loggerhead sea turtles may use The Ocean Cleanup project area during migration (Kobayashi et al., 2008; Abecassis et al., 2013; Briscoe et al., 2016a,b). However, most juvenile loggerheads tracked by satellite tags were more commonly found in the northwest Pacific and not in The Ocean Cleanup project area (Abecassis et al., 2013).

Loggerheads do not nest in coastal southwest Canada and are unlikely to be found in coastal areas. After the breeding season, females go to feeding areas on the continental shelf off the coast of Mexico. Mating occurs during migration. Adults feed on a wide variety of benthic fauna such as clams, crabs, sea urchins, sponges, and fish. Young turtles feed on jellyfish, *Sargassum*, gastropods, and crustaceans. The major threat to adult loggerheads is interactions with fisheries, including entanglement with longlines (Lewison et al., 2004).

4.3.5.3 Olive Ridley Sea Turtle

The Olive ridley turtle is a pantropical species that lives mainly in pelagic areas but has been sighted in coastal areas. Olive ridley turtles do not nest in coastal southwest Canada. This species nests on the west coast of Mexico but has been sighted as far north as Oregon. This turtle is omnivorous and feeds mainly on algae, lobster, tunicates, mollusks, shrimp, and fish (NOAA, 2014b).

4.3.5.4 Leatherback Sea Turtle

The leatherback turtle is better suited to cold waters than other sea turtles. This turtle is a highly pelagic species, which approaches the coastal waters during the breeding periods. Several recent studies employing satellite tags indicate that leatherbacks routinely migrate along a trans-Pacific route in search of food (Benson et al., 2007, 2011). Consequently, it is likely that leatherbacks will be present in the project area during the S002 deployment as well as possibly during the transit to and from the Vancouver area and the NPSG.

The leatherback turtle does not nest in coastal southwest Canada and is rarely sighted in waters offshore of British Columbia (Government of Canada, 2021t). The eastern Pacific subpopulation nests in Central America from Mexico to Ecuador (NOAA, 2016a). Leatherback turtles feed mainly on jellyfish, tunicates, and other epipelagic soft-bodied invertebrates.

4.3.5.5 Green Sea Turtles

Green turtles are widely distributed in tropical and subtropical waters near continental coasts and islands. Green turtles do not nest in coastal southwest Canada and are most common south of San Diego where foraging grounds stretch from southern California to Chile (NOAA, 2016b). The primary nesting areas in the Pacific are in Mexico, the Hawaiian Islands, and many of the small islands in the south Pacific. Green sea turtles are entirely herbivorous, feeding mainly on algae and seagrasses (NOAA, 2016b).

4.3.5.6 Hawksbill Turtle

The hawksbill turtle is the most tropical of all sea turtles and does not nest in coastal southwest Canada. Pacific nesting beaches are mainly on the Hawaiian Islands, south Pacific islands, and on beaches of Nicaragua and El Salvador in South America. The hawksbill turtle is carnivorous and feeds on a variety of organisms such as sponges and various invertebrates (NOAA, 2014c). It is possible that individuals may occur in the central Pacific near the deployment of S002, but hawksbill turtles will not be present in northern areas in the Vancouver area.

4.3.6 Coastal and Oceanic Birds

4.3.6.1 Coastal Birds

The Vancouver Island area and surrounding estuaries provide essential habitat for millions of birds on the Pacific Flyway; a bird migration corridor along the Pacific Coast that stretches as far north as northern Canada and Alaska, and as far south as the southern tip of South America (**Figure 4-1**). It is estimated that up to eight million waterfowl transit through coastal British Columbia during annual migrations (Ducks Unlimited, 2021).

British Columbian coastal areas are comprised of a wide variety of habitats such as coniferous and deciduous forests, tidal flats, ponds, tidal marshes, subtidal areas with eel grass, and open ocean areas that support a wide variety of waterbirds, and inland areas of grasslands (South Coast Conservation Program, nd). The estuaries of British Columbia are of vital importance to migrating and wintering waterfowl. The main river estuary near Vancouver is the Fraser River, which runs more than 1,300 km from the Rocky Mountains until it empties into the Strait of Georgia just south of Vancouver. The Estuary has more than 32,000 ha of mud and sandflats. Mudflats on Roberts Bank have been recorded to have over 500,000 western sandpipers present on a single day (Western Hemisphere Shorebird Reserve Network, 2019). Some of the Estuary is protected, with some areas designated as Provincial Wildlife Management Areas. Additionally, the Alaskan National Wildlife Area is listed as a Ramsar Wetland of International Importance.

Common coastal species present in the Estuary are a subset of waterbirds in the families Gaviidae (loons), Podicipedidae (grebes), Phalacrocoracidae (cormorants), Ardeidae (herons, bitterns, and allies), Rallidae (rails, gallinules, and coots), Gruidae (cranes), and Laridae (skuas, gulls, terns, and skimmers), among others. Over 75 species of waterbirds have been identified in British Columbia (Birds Canada, 2020), and more than 250 species of birds have been identified within the metropolitan Vancouver area alone (Vancouver Bird Advisory Committee, 2015). A comprehensive 1995 report (Stevens, 1995) identified 356 bird species from the two climate zones in the vicinity of Vancouver Island, within the coastal Douglas fir and coastal Western Hemlock zones.

Figure 4-1. The Pacific flyway migration route in relation to the Vancouver area. (Image from: Vancouver Bird Advisory Committee, 2015).

Four Important Bird Areas (IBAs) are located in the vicinity of Vancouver: Fraser River Estuary, English Bay and Burrard Inlet, Greater Vancouver Watershed, and Pacific Spirit Regional Park (Vancouver Bird Advisory Committee, 2015). An additional five IBAs have been designated in the marine waters around Vancouver: Snake Island, Porlier Pass, Active Pass, Sidney Channel, and Chain and Great Chain Islets (IBA Canada, 2001). **Table 4-14** lists the threatened and endangered birds found in the vicinity of Vancouver, British Columbia.

Table 4-14. Threatened and endangered birds potentially present in the Vancouver area. Data compiled from the International Union for Conservation of Nature (IUCN, 2021) and the Government of Canada's species at risk public registry (Government of Canada, 2021u).

Common Name	Scientific Name	Presence in Coastal Canada	Foraging/ Migration Area	SARA/COSEWIC Status	IUCN Red List Status
Barn Swallow	*Hirundo rustica*	Year Round	Open fields	T,T	Least Concern
Black Swift	*Cypseloides niger*	Year Round	Variable	E,E	Vulnerable
Common Nighthawk	*Chordeiles minor*	May-August	Variable	T, SC	Least Concern
Horned Lark	*Eremophila alpestris strigata*	Year Round	Open areas	E,E	Least Concern (as *E. alpestris*)
Lewis's Woodpecker	*Melanerpes lewis*	Year Round	Scrubland	T,T	Least Concern
Marbled Murrelet	*Brachyramphus marmoratus*	Year Round	Protected marine lagoons	T,T	Endangered

Table 4-14. (Continued).

Common Name	Scientific Name	Presence in Coastal Canada	Foraging/ Migration Area	SARA/COSEWIC Status	IUCN Red List Status
Northern Goshawk	*Accipiter gentilis laingi*	Year Round	Forests	T,T	Least Concern (for *A. gentilis*)
Northern Saw-whet Owl	*Aegolius acadicus brooksi*	Year Round	Open Forests	T,T	Least Concern (for *A. acadicus*)
Olive-sided Flycatcher	*Contopus cooperi*	Year Round	Open areas	T, SC	Near Threatened
Pink-footed Shearwater	*Ardenna creatopus*	Year Round	Coastal Ocean	E,E	Vulnerable
Red Knot	*Calidris canatus roselaari*	Fall	Sandflats	T, NL	Near Threatened (for *C. canatus*)
Short-tailed Albatross	*Phoebastria albatrus*	Year Round	Open Ocean	T,T	Vulnerable
Spotted Owl	*Strix occidentalis caurina*	Year Round	Old Growth Forest	E,E	Near Threatened (for *S. occidentalis*)
Western Screech-Owl	*Megascops kennicottii kennicottii*	Year Round	Coastal Forests	T,T	Least Concern (for *M. kennicott*)
	Megascops kennicottii macfarlanei	Year Round	Riparian Forests	T,T	

COSEWIC = Committee on the Status of Endangered Wildlife in Canada; IUCN = International Union for the Conservation of Nature; SARA = Species at Risk Act. E = Endangered; NL = Not Listed; SC = Special Concern; T = Threatened

4.3.6.2 Oceanic Birds

Orders of seabirds relevant to the project area include Procellariiformes (e.g., albatrosses, petrels); Pelecaniformes (e.g., pelicans, cormorants, boobies, frigate birds); Charadriiformes (e.g., gulls, terns, alcids); Gaviiformes (loons); and Podicipediformes (grebes). Seabirds can be highly pelagic, coastal, or in some cases spend a part of the year away from the sea entirely.

In the open ocean waters of the NPSG, mainly pelagic seabirds are present (**Table 4-15**), especially during their migratory period. Pelagic seabirds present in the NPSG are known to nest along coastal areas or on islands in the Pacific Ocean. In the North Pacific, breeding generally occurs during spring and summer. When not breeding, these birds forage along coastal areas or in the open ocean. The CCS is an attractive area for birds due to its high nutrient content and corresponding high prey availability (Sydeman et al., 2012). Species migrate great distances to feed within the CCS.

Table 4-15. Common birds in the North Pacific Ocean. Data compiled from IUCN and BirdLife International (IUCN, 2021; BirdLife International, 2021).

Common Name	Scientific Name	Foraging/ Migration Season	Foraging/Migration Area	IUCN Red List Status
Brown Booby	*Sula leucocaster*	Year Round	Pacific Ocean	Least Concern
Red footed Booby	*Sula sula*	March-October	Open Ocean, only in far South of Northeast Pacific and Hawaii	Least Concern
Masked Booby	*Sula dactylatra*	Year Round	Open Ocean, only in South Northeast Pacific and Hawaii	Least Concern
Black-footed Albatross	*Phoebastria nigripes*	May-October	North Pacific Ocean	Near Threatened
Laysan Albatross	*Phoebastria immutabilis*	August-November	North Pacific Ocean. Seen in Northeastern Pacific but prefers West Pacific side	Near Threatened

Table 4-15. (Continued).

Common Name	Scientific Name	Foraging/ Migration Season	Foraging/Migration Area	IUCN Red List Status
Short tailed Albatross	*Phoebastria albatrus*	June-October	North Pacific-especially Alaska but spotted around Hawaii and California	Vulnerable
Ashy Storm-petrel	*Oceanodroma homochroa*	November-April	California Current System	Endangered
Black-vented Shearwater	*Puffinus opisthomelas*	July-February	California Current System and North Pacific	Near Threatened
Cassin's Auklet	*Ptychoramphus aleuticus*	Year Round	Along North American West Coast	Near Threatened
Murphy's Petrel	*Pterodroma ultima*	November-April	Between Hawaii and California, at least 64 km (35 nmi) offshore	Least Concern
Pink-footed Shearwater	*Puffinus creatopus*	April - October	Along continental shelf of U.S. West coast and Canada	Vulnerable
Wedge-Tailed Shearwater	*Ardenna pacifica*	Year Round	Tropical oceans (35°N-35°S)	Least Concern
Sooty Shearwater	*Ardenna grisea*	April - October	Circular migration, Full Pacific Ocean	Near Threatened
Leach's Storm Petrel	*Hydrobates (Oceanodroma) leucorhoa*	November-April	Pacific Ocean	Vulnerable

IUCN = International Union for Conservation of Nature.

During transit and deployment of The Ocean Cleanup's System 001 in the NPSG in 2018, a total of 10 unique species of birds were observed. Observations were not enumerated, but taxa observed included Black-footed Albatross, Laysan Albatross, Red-tailed tropicbird (**Image 4-5**), White-tailed tropicbird, Blue-footed Booby, Masked Booby, Brown Booby, Rump-band Storm Petrel, Osprey, and Sanderling (Seiche, 2019).

Image 4-5. A Red-tailed tropicbird observed during The Ocean Cleanup's System 001 deployment in the North Pacific Subtropical Gyre in 2018. From: Seiche, 2019.

During transit and deployment of The Ocean Cleanup's System 001B in the NPSG in 2019, 106 bird observations were made over the course of 157 days. The majority of bird sightings were comprised of just two species: Black-footed Albatross (32 observations) and Masked Booby (26 observations; **Image 4-6**). Other observations included unidentified Albatross's (15 observations), Laysan Albatross (9 observations), Red-tailed tropicbird (3 observations), Western Gull (2 observations), and unidentified Booby's (2 observations). Fifteen observations of unidentified birds were also made (The Ocean Cleanup, 2020).

Image 4-6. A Masked Booby resting on a towhead of The Ocean Cleanup's System 001B in the North Pacific Subtropical Gyre in 2019. From: The Ocean Cleanup, 2020.

4.3.7 Protected Areas

There are no protected areas in the vicinity of the S002 deployment location in the NPSG. However, the project vessels will transit past several coastal protected areas, including Race Rocks Ecological Reserve, Juan de Fuca Park, Pacific Rim National Park Reserve of Canada, and Olympic National Park in the United States.

One marine protected area, the Endeavour Hydrothermal Vents Marine Protected Area (MPA), is in the vicinity of potential transit operations offshore Vancouver. Located approximately 260 km southwest of Vancouver Island, the vents are located along a narrow seafloor valley along the Juan de Fuca Ridge approximately 14 km long and 1.5 km wide. It is known that there are as many as 572 vent chimneys spread over the region (Clague et al., 2020).

The Endeavour Hydrothermal Vents MPA is located within a broad area known as the Canadian Offshore Pacific Area of Interest (**Figure 4-2**). The area is approximately 133,000 km^2 in size and is meant to protect and conserve unique seafloor features and the ecosystems which they support (Government of Canada, 2020b).

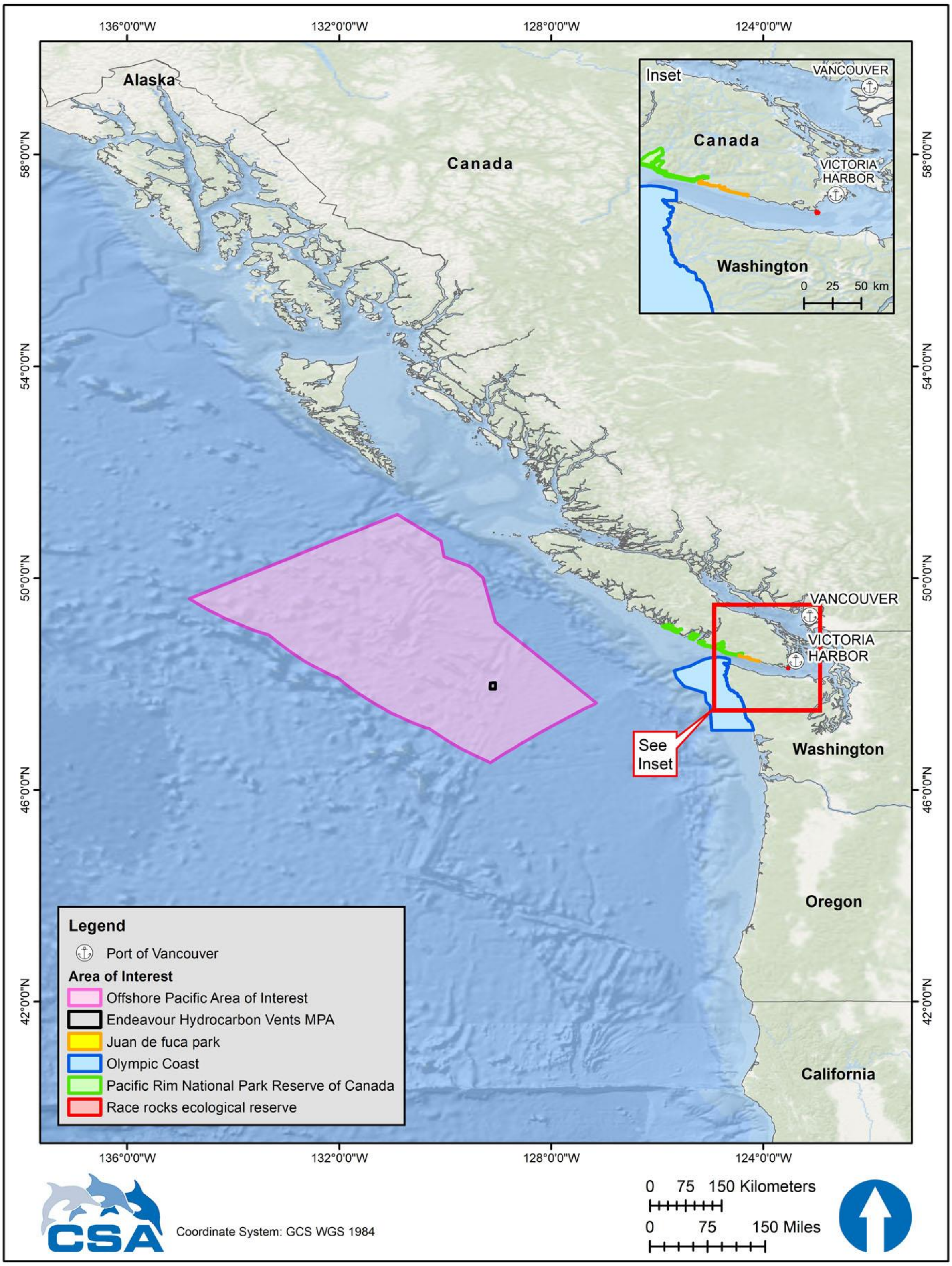


Figure 4-2. The Canadian Offshore Pacific Area of Interest and the Endeavour Hydrothermal Vents Marine Protected Area offshore Vancouver Island. Adapted from: Government of Canada, 2020b.

Depending on the exact transit route chosen, the project vessels may pass through or near the Canadian Offshore Pacific Area of Interest (**Figure 4-3**). Summary characteristics of the two protected areas described above are presented in **Table 4-16**.

Table 4-16. Summary characteristics of the Endeavour Hydrothermal Vents Marine Protected Area offshore Vancouver Island in the vicinity of the transit routes for the Ocean Cleanup System.

Name	Area (km^2) [nmi^2]	Designated (Year)	Major Features
Endeavour Hydrothermal Vents Marine Protected Area	97 [28.3]	2003	The Endeavour segment of the Juan de Fuca Ridge is an active seafloor spreading zone. Across five vent fields, black smokers, vent chimneys, and other vent structures emit water at up to 300°C. Fauna associated with the vents include numerous species of brittlestars, worms, and an incredibly diverse microbial community.
Offshore Pacific Area of Interest	133,019 [38,782]	2017	Comprising more than 2.3% of all of Canada's maritime territory, this large marine area is designed to protect several interlinked ecosystems, including seamounts and hydrothermal vents. The Area contains more than 90% of Canada's hydrothermal vents.

km^2 = square kilometers; nmi^2 = square nautical miles.

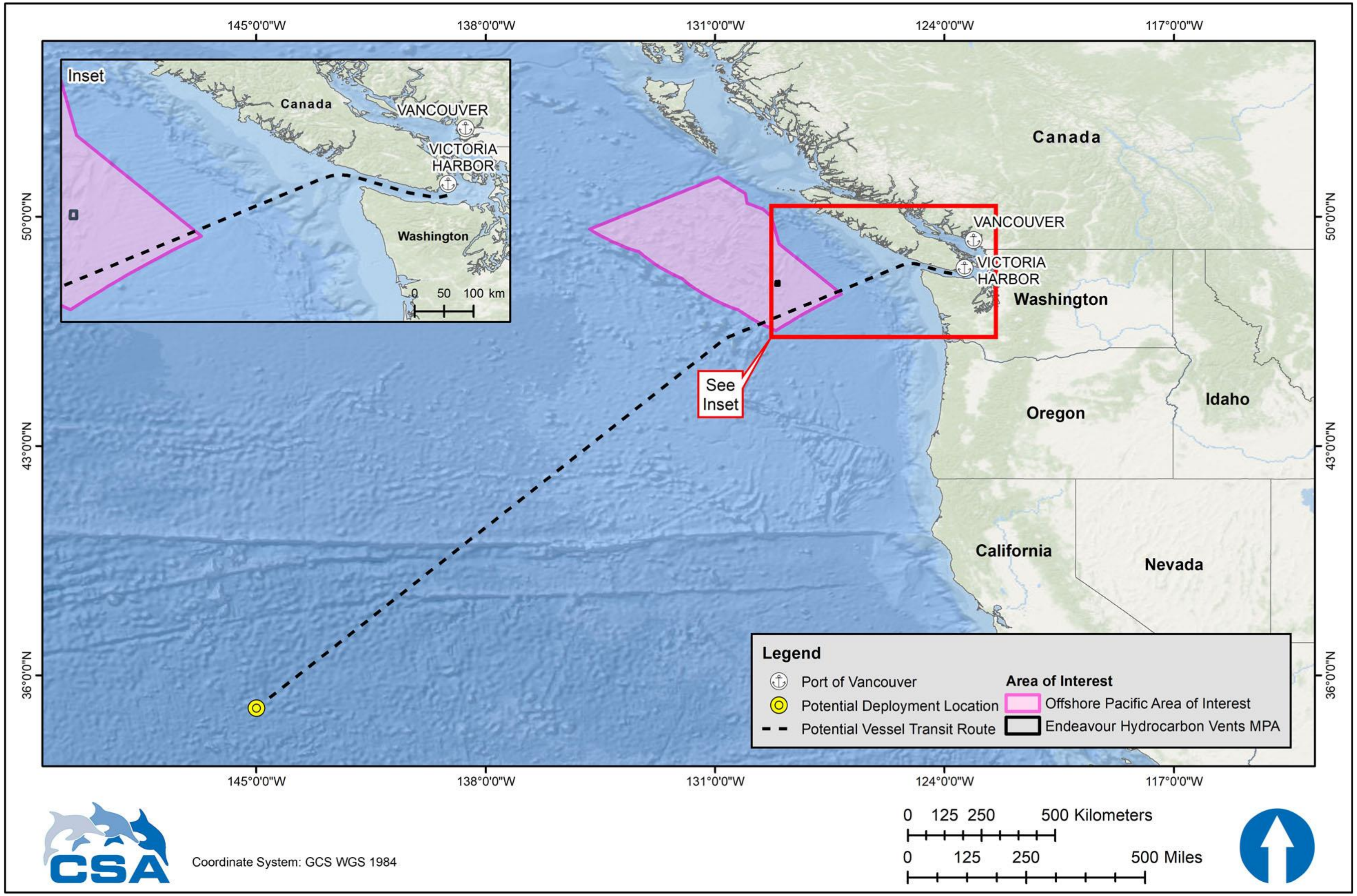


Figure 4-3. Canadian Offshore Pacific Area of Interest and the Endeavour Hydrothermal Vents Marine Protected Area relative to a hypothetical transit route from the Vancouver area to the North Pacific Subtropical Gyre.

4.3.8 Biodiversity

No significant impacts to biodiversity are expected from The Ocean Cleanup activities. While deployment of S002 may have impacts on individuals of a variety of species (see impacts discussion in **Chapter 5**), it is not expected that any detrimental impacts will occur on a species level that would result in harm to biodiversity.

4.4 SOCIAL ENVIRONMENT

4.4.1 Commercial and Military Vessels

Commercial vessel activity through the Strait of Juan de Fuca, Salish Sea, and the Strait of Georgia, is high. Vancouver is Canada's busiest port, with more than 16,000 hectares of water serving approximately 3,200 commercial ship visits each year (Port of Vancouver, 2021).

The Canadian Coast Guard (CCG) is responsible for issuing Notices to Shipping (NOTSHIP), a mechanism to inform both commercial and recreational mariners about hazards to navigation and to share other important information. Verbal NOTSHIP alerts are broadcast by radio by Canada's Marine Communications and Traffic Services, while written NOTSHIP alerts are issued when the hazard location is beyond broadcast range or when the information remains in effect for an extended period of time (Port of Vancouver, 2020). The Ocean Cleanup vessels will monitor NOTSHIP notifications prior to and during transit from the Vancouver area. Canadian Forces Base Esquimalt is Canada's Pacific naval base. Located on the southern end of Vancouver Island adjacent to the Strait of Juan de Fuca, it is over 12,000 acres in size. No impacts on the Base are expected from transit activities, but military vessels may be present in the vicinity when the project vessels are transiting past.

Numerous commercial and recreational vessels will be located within from the Salish Sea during transit of the project vessels to and from the Vancouver area. **Figure 4-4** presents established shipping lanes in the vicinity of the Vancouver area and a potential route for the project vessels.

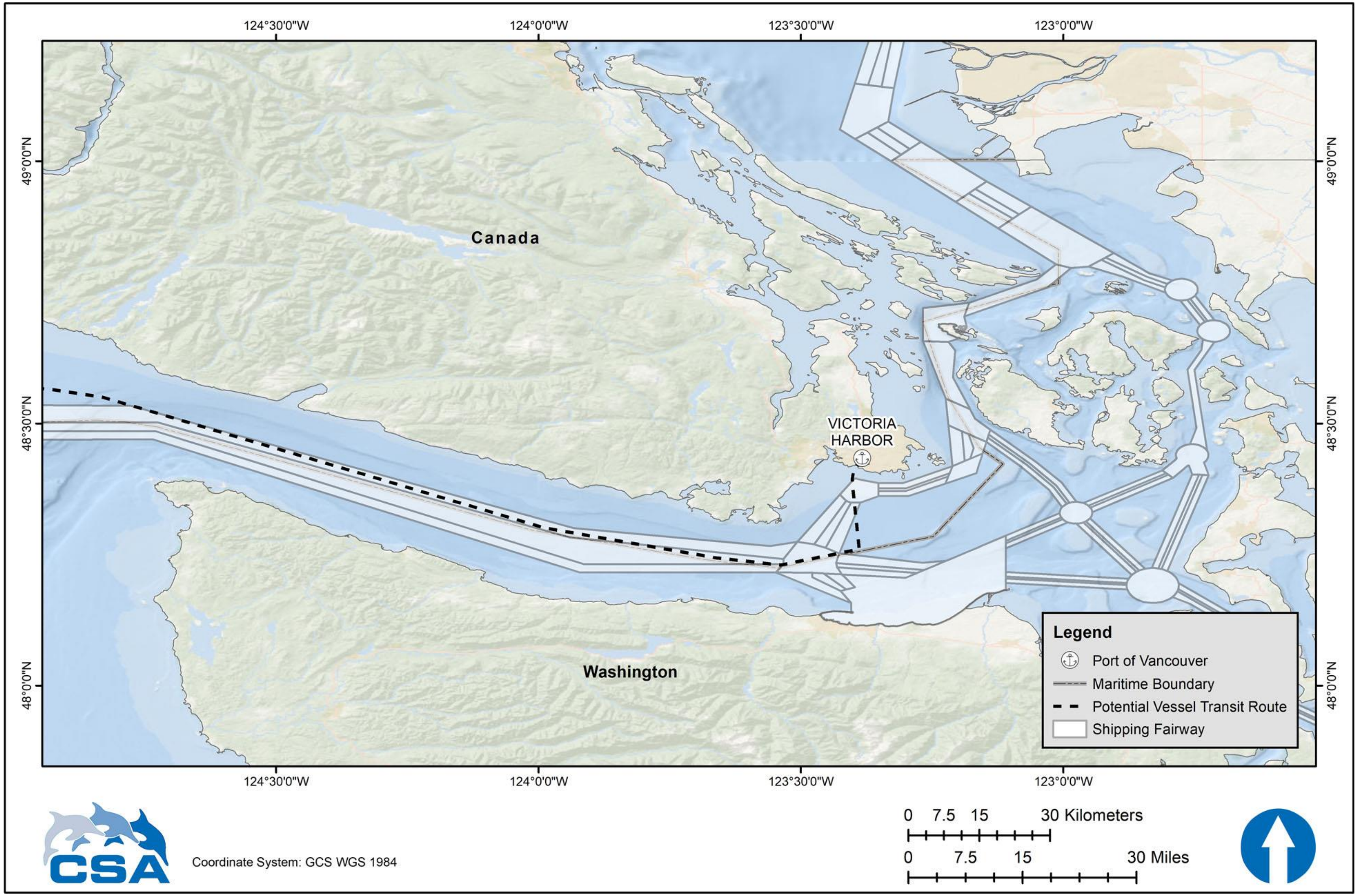


Figure 4-4. Shipping routes in the vicinity of Vancouver.

5.1 IMPACT ASSESSMENT METHODOLOGY

Based on the project description (**Section 2.0**), impact producing factors (IPFs) associated with the transit and deployment of S002 have been identified for both routine operations and potential accidents/unplanned events. A preliminary screening exercise was completed (**Section 4.1**) to identify biological and social resources that will not be affected by The Ocean Cleanup activities or where impact consequence was deemed, *a priori*, to be negligible. Resources for which more extensive analysis will not be performed as part of this EIA include air quality; sediment quality; water quality; benthic communities; archaeological resources; human resources, land use and economics; recreational resources and tourism; and physical oceanography.

Table 5-1 identifies the potential sources of impact associated with the proposed activities and the biological and social resources that may be affected by particular activities. Some IPFs that are expected to result in similar or identical impacts to a particular resource were combined to reduce redundancy in reporting.

Table 5-1. Matrix of potential impacts from The Ocean Cleanup proposed transit and deployment activities for S002.

Project Activity/ Impact Producing Factor (IPF)	Environmental Resource							
	Biological							Social
	Fish and Fishery Resources	Plankton	Neuston	Marine Mammals	Sea Turtles	Coastal and Oceanic Birds	Protected Areas	Commercial and Military Vessels
S002 – Entanglement/Entrapment	●	●	●	●	●	●	--	--
S002 – Attraction/Ingestion of Plastics	●	●	●	●	●	●	--	--
Vessel – Physical Presence/Strikes	●	--	--	●	●	●	●	●
Noise and Lights	●	●	●	●	●	●	--	--
Loss of Debris	--	--	--	●	●	●	--	--
Accidental Fuel Spill	●	●	●	●	●	●	●	--

● indicates a potential impact to a resource; -- indicates no or negligible potential for impact.

The only accident evaluated in this EIA is a fuel spill, as there are no activities proposed by The Ocean Cleanup that have a reasonable likelihood of resulting in a large spill of crude oil or other chemicals. Most small spills that occur during offshore operations are ≤1 barrel (bbl)[5] in volume. In the Gulf of Mexico, median volume for spills of 1 to 10 bbl is 3 bbl (Anderson et al., 2012). The most common cause of a small spill would be a rupture of the fuel hose resulting in a loss of contents (<3 bbl of fuel). Consequently, a spill size of 3 bbl is used as a hypothetical spill scenario for this EIA.

Other potential accidents involving the S002 could include: 1) breaking up at sea, 2) sinking, or 3) becoming entangled with the tow vessels while deployed. Such incidents are considered unlikely due to the engineering design of the S002, sensor and positioning system redundancy, and multi-layered safety precautions. Safety measures have been put in place during the design and fabrication phases to avoid or minimize potential impacts resulting from failure of the S002. If damage that

[5] One barrel equals 42 U.S. gallons, 35 Imperial gallons, or approximately 159 L.

potentially interferes with the safe operation of the S002 is detected, the system (or any broken parts) will be brought to shore immediately.

S002 is constructed primarily of Dyneema® netting, buoys, float line, ballast line, and marine connectors and comprised of the RS (wings) with attached towing lines and the RZ with a bridle. As outlined in **Section 2.1.1**, the RS is modular in design and comprised of two 391-m wings which are designed to prevent underflow, prevent overtopping, and limit drag effect. The RS is comprised of 17 sections each 23 m long for a total of 391 m each and include a float line, ballast line, and net attached between the float and ballast lines. The float line consists of single HD fenders with a permeable cover and has 158.6 kg of floatation for each section. The wing section above the mouth of the RZ has 354 kg of floatation capacity to prevent overflow. The RZ is constructed of Dyneema® netting, buoys, lines, ballast chain, and marine connectors and is comprised of the RZ entrance, safe section, and extraction section with bridle.

The RS design will allow the integration of, and provide stability for, installation of a global training tracking system (GTTS), which is comprised of a series of trackers that are evenly distributed along the length of S002. Other components of the RS include motion reference units (MRUs), lanterns, seven banana pingers (one on the retention area; three on each wing), a multiple camera systems to monitor at the RZ entrance and accumulation area (one forward- and 2 backward-looking), and a series of green-flashing deterrent lights placed 46 m apart along the system wings. In the event the S002 separates at sea, the GTTS signals will show the separated parts further apart than designed. To the extent feasible, with due consideration to risks to human and marine health and safety, The Ocean Cleanup will recover S002 parts and debris generated should the system break apart. In the unlikely event that such an accident was to occur, potential environmental impacts are anticipated to be negligible to minor, as all the major parts of S002 are intended to remain floating and available for recovery.

Potential impacts of S002 will be evaluated using the methodology described below. Impact consequence and impact likelihood are two factors used to determine potential impact significance (**Figure 5-1**).

5.1.1 Determination of Impact Consequence

Impact consequence reflects an assessment of an impact's characteristics on a specific resource (e.g., fish and fishery resources, marine mammals, etc.) arising from one or more IPFs. Impact consequence is determined regardless of impact likelihood. Impact consequence classifications include Positive (Beneficial), Negligible, Minor, Moderate, and Severe, as defined below.

For negative impacts[6], the determination of impact consequence is based on the integration of three criteria: intensity, extent, and duration of the impact. These criteria are defined below; four levels of consequence can be attributed to a negative impact based on a rigorous analysis explained for each resource. When it is appropriate, calculations have been made to characterize quantitatively the intensity and/or the extent of the impacts. These calculations are explained for each of the resources concerned. Positive impacts[7] are noted, but their consequence is not qualified.

[6] A negative impact is an impact where the change to the current situation of the resource is generally considered adverse or undesirable.

[7] A positive impact is an impact where the change to the current situation of the resource is generally considered better or desirable.

5.1.2 Intensity of an Impact

The intensity relates to the degree of disturbance associated with the impact and the alteration of the current state of the host environment. Three levels of intensity can be attributed[8]:

- **Low**: Small adverse changes unlikely to be noticed or measurable against background activities. For the social environment, changes may be noticed only by a few individuals;
- **Moderate**: Adverse changes that can be monitored and/or noticed but are within the scope of existing variability without affecting the resource's integrity or use in the environment. For the social environment, adverse change that affects several people, but not the entire community; or
- **High**: For the physical environment, extensive or frequent violation of applicable air or water quality standards/guidelines, or widespread contamination of sediments with hydrocarbons, toxic metals, or other toxic substances. For the biological environment, extensive damage to habitats to the extent that ecosystem functions and ecological relationships would be altered, or numerous deaths or injuries of a protected species and/or continual disruption of their critical activities. For the social environment, extensive adverse change that is far-reaching and widely recognized, it significantly limits the use of a resource by a community or a regional population, or its functional and safe use is seriously compromised. An impact potentially resulting in the death of one or more community members is also considered of high intensity.

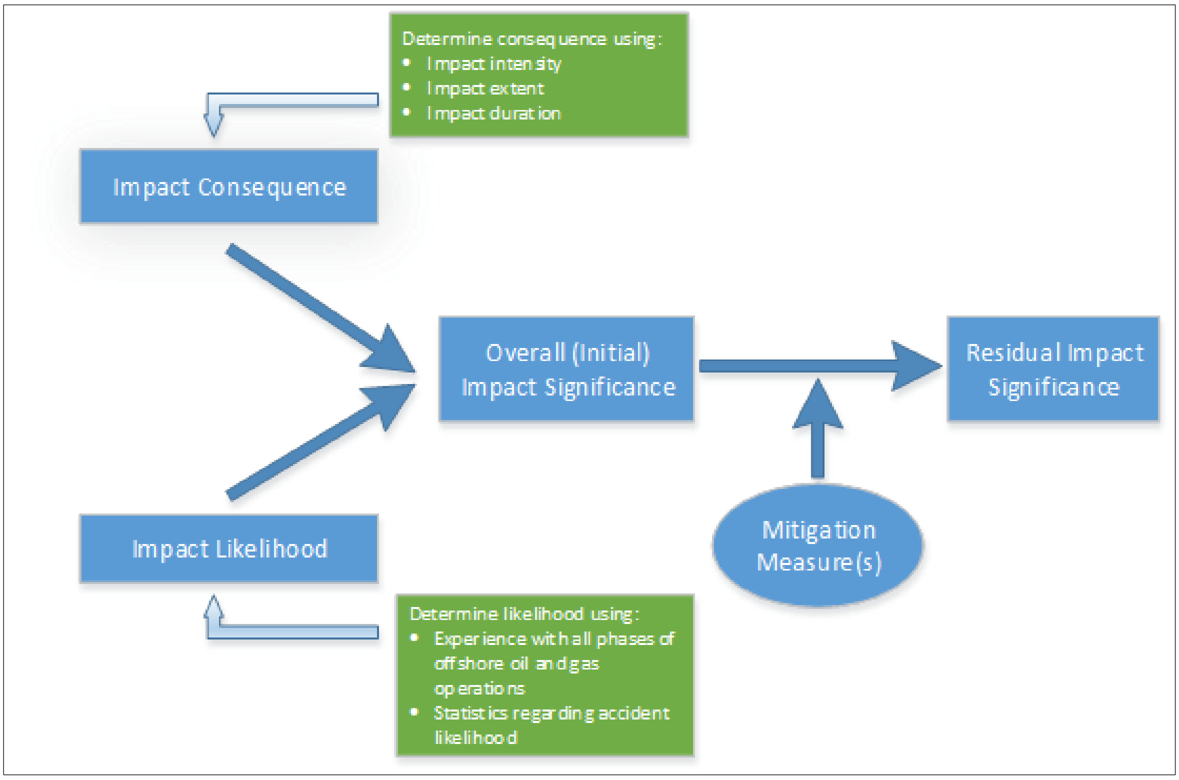


Figure 5-1. Impact assessment flow chart.

[8] The definitions presented here are general descriptions of the levels for each criterion. Not all resources have been included as examples, but specific explanations are provided in the assessment when needed.

5.1.3 Extent of an Impact

The geographic extent of an impact expresses how widespread the impact is expected to be. It represents the area that will be affected, directly or indirectly. An impact extent is classified by the following levels:

- **Immediate vicinity:** Limited to a confined space within the area of interest (AOI), generally within 2 km of project activities;
- **Local:** The impact has an influence that goes beyond the AOI, but stays within a relatively small geographic area (i.e., generally about 5 to 20 km from the source of impact); or
- **Regional:** The impact affects a large geographical area, generally more than 20 km from the source of impact.

In general, the extent of all impacts to resources from The Ocean Cleanup activities related to deployment of S002 would be immediate vicinity, except for potential behavior modifications for marine mammals due to noise, which would be local, and for neuston, which would range from local to regional.

Duration of an Impact

The duration of an impact describes the length of time over which the effects of an impact occur. It is not necessarily the same as the length of time of an activity or an IPF as an impact can sometimes continue after the source of impact has stopped or the impact can be shorter if there is an adaptation. Therefore, this period can include the recovery period or the adaptation period of the affected resource. The duration of the impact can be:

- **Short term**: The impacts are felt continuously or discontinuously over a limited period, generally during the project period of activity, or when the recovery or adaptation period is less than a year; or
- **Long term**: The impacts are felt continuously or discontinuously beyond the life of the proposed project.

The duration for all impacts associated with The Ocean Cleanup project for this evaluation is expected to be short term, although the potential for long term impacts will be assessed (e.g., neuston).

Table 5-2 lists the combinations of criteria that have been used to delineate impact consequence.

Table 5-2. Matrix of impact consequence determinations for negative impacts.

Intensity	Extent	Duration	Consequence Criteria			
			Negligible	Minor	Moderate	Severe
Low	Immediate vicinity	Short term	●	-	-	-
	Local	Short term	●	-	-	-
	Regional	Short term	●	-	-	-
	Immediate vicinity	Long term	●	-	-	-
	Local	Long term	-	●	-	-
	Regional	Long term	-	●	-	-

Table 5-2. (Continued).

Intensity	Extent	Duration	Consequence Criteria			
			Negligible	Minor	Moderate	Severe
Moderate	Immediate vicinity	Short term	-	●	-	-
	Local	Short term	-	●	-	-
	Regional	Short term	-	●	-	-
	Immediate vicinity	Long term	-	●	-	-
	Local	Long term	-	-	●	-
	Regional	Long term	-	-	●	-
High	Immediate vicinity	Short term	-	-	●	-
	Local	Short term	-	-	●	-
	Regional	Short term	-	-	●	-
	Immediate vicinity	Long term	-	-	●	-
	Local	Long term	-	-	-	●
	Regional	Long term	-	-	-	●

- = not applicable.

5.1.4 Likelihood of an Impact

The likelihood of an impact describes the probability that an impact will occur. The likelihood of impact occurrence was rated using the following categories:

- Likely (>50% likelihood);
- Occasional (10% to 49% likelihood);
- Rare (1% to 9% likelihood); and
- Remote (<1% likelihood).

Impacts are evaluated or predicted 1) prior to the implementation of mitigation measures; and 2) following implementation of these measures. Mitigation measures are identified based on industry best practice, international standards (e.g., MARPOL requirements), or measures deemed applicable and practicable by The Ocean Cleanup. Impacts that remain after adoption or implementation of mitigation measures are described as residual impacts. To summarize the overall significance of each impact, impact consequence and likelihood were combined using professional judgment and a risk matrix, as shown in **Table 5-3**. According to this matrix, the overall impact significance for biological and social negative impacts using a numeric, descriptive, and color-coded approach is rated as follows:

- 1 – Negligible;
- 2 – Low;
- 3 – Medium; and
- 4 – High.

Table 5-3. Matrix combining impact consequence and likelihood to determine overall impact significance.

Likelihood vs. Consequence		Decreasing Impact Consequence → Beneficial	Negligible	Minor	Moderate	Severe
Decreasing Impact Likelihood	Likely	Beneficial (no numeric rating applied)	1 – Negligible	2 – Low	3 – Medium	4 – High
	Occasional		1 – Negligible	2 – Low	3 – Medium	4 – High
	Rare		1 – Negligible	1 – Negligible	2 – Low	4 – High
	Remote		1 – Negligible	1 – Negligible	2 – Low	3 – Medium

Impacts of Negligible consequence were assigned the lowest overall significance value (1 – Negligible), regardless of impact likelihood. Severe impacts were assigned the highest significance value (4 – High) if the impacts were Likely, Occasional, or Rare and assigned a lower value (3 – Medium) if the likelihood was Remote. The most significant impacts (those rated as 3 – Medium or 4 – High) were primary candidates for mitigation. Mitigation was also considered for lower overall significance levels (1 – Negligible and 2 – Low) to further reduce the likelihood or consequence of impacts. A comprehensive discussion of the mitigation measures and corporate/subcontractor policies that The Ocean Cleanup will follow during their proposed activities will be presented under separate cover in an Environmental Management Plan.

5.2 POTENTIAL IMPACTS FROM PROPOSED ACTIVITIES

The long-term beneficial impacts from The Ocean Cleanup project are discussed in **Section 5.2.1**, while the environmental consequences discussed in subsequent sections of **Section 5.0** address the potential impacts that could be incurred as a result of the transiting and deployment/operation of S002. For each resource, the IPFs identified in **Table 5-1** were further examined and refined to identify aspects of those factors specific to the resource under evaluation. The impact assessment for each resource includes a list of the relevant IPFs, a discussion concerning the effects of the IPF on the resource, and the significance of the impact on the resource from the IPF. Summary impact tables are presented for the impact rating for determining impact significance prior to and following implementation of mitigation measures.

5.2.1 Long-Term Impacts from Project Activities

Plastics are manufactured from polymers retrieved from fossil fuels (gas, coal, or oil). Plastic gets its characteristics due to a blend of added chemicals called additives. Because of its light, cheap, strong and durable characteristics, plastic is an ideal product for manufacturing everyday items (Thompson et al., 2009). The production of plastic has increased exponentially over the past 60 years and continues to increase, especially in areas with growing economies such as China and southeast Asia (PlasticsEurope, 2016). Most consumer plastics are either High Density Polyethylene (HDPE) or Low Density Polyethylene, Polypropylene, Polyethylene Terephthalate or Polyvinylchloride.

Because of their environmental persistence, plastics can stay in oceans for decades (Barnes et al., 2009). Studies show that in 2010, 4.8 to 12.7 million metric tons entered the ocean annually from coastal populations (Jambeck et al., 2015), while plastic input from inland rivers was estimated to add between 0.79 and 1.52 million tons to the world's oceans (Lebreton et al., 2017). Total worldwide plastics production reached 359 million tons in 2018 (PlasticsEurope, 2019), approximately 30% higher than the 265 million tons in 2010 (PlasticsEurope, 2011).

When macroplastics break down due to degradation (mechanical, biological, or UV degradation), microplastics can form. Microplastics, defined by NOAA as plastic pieces <5 mm in size, are hard if not impossible to remove form the marine environment, and their numbers will increase exponentially over time as macroplastics present in the environment continue to break down (Thompson et al., 2004). It was found that microplastic content in the North Pacific increased by two orders in terms of weight and numbers between 1972-1987 and 1999-2010 (Goldstein et al., 2012). A recent study performed by The Ocean Cleanup estimated an amount of 80 kilotons of plastic in an area of 1.6 million km^2. Approximately six kilotons were defined as microplastic, while the remaining 74 kilotons were considered microplastic; microplastics made up 94% of the abundance of plastic pieces however. Microplastics in the marine environment will also continue to break down, creating small microparticles and nanoparticles (e.g., see Gigault et al., 2018; Yee et al., 2021).

Both microplastics and macroplastic fragments are often mistaken for food and are ingested by biota in all trophic levels. Although ingestion of plastic is not directly lethal to the individual (only in 4% of the cases), it does have negative effects such as reduced fitness, toxicity caused by absorption of toxins, a false feeling of satiation and eventually starvation (Gall and Thompson, 2015). Birds are especially vulnerable to the effects of plastic ingestion due to their small gizzards and many species' inability to regurgitate indigestible items (Azzarello and van Vleet, 1987).

López-Martínez et al. (2021) reviewed various approaches and protocols employed to assess macro- and microplastic ingestion in marine vertebrates (e.g., sea turtles, cetaceans, fishes). Their analysis of 112 studies indicated that the highest plastic ingestion by organisms from the Mediterranean and northeast Indian Ocean exhibited significant differences among plastic types, varying by animal group and differences in color and type of polymer. For example, in sea turtles, white plastics (66.6%), fibers (54.5%), and LDPE polymers (39.1%) were prevalent, compared to white macro- and microplastics (38.3%), fibers (80.0%), and polyamide polymers (49.6%) in cetaceans. In fishes, transparent plastics (46.0%), fibers (66.7%), and polyester polymers (36.2%) predominated. In general, considering all study results, the authors determined that clear fiber microplastics were the predominant types ingested by marine megafauna on a worldwide basis (López-Martínez et al., 2021).

Because of their increased surface area to volume ratio relative to macroplastics, microplastics release more chemical additives into the environment. Some of these additives are highly toxic or can increase the risk of disease. Examples of such additives are residual monomers, which are considered toxic to humans and ecosystems (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection [GESAMP], 2016). These additives are released after ingestion and can accumulate in individuals (Wright et al., 2013). Additives are stored in body tissue, which may result in food chain pollution by bioaccumulation (Hammer et al., 2012). In addition, plastics in the ocean attract other chemicals because of their hydrophobic nature, increasing the overall toxicity of floating plastics (Andrady, 2011).

The long-term benefits of the removal of macroplastics and other marine debris (i.e., ghost nets) from the NPSG include 1) the long-term reduction in the potential impact of entanglement of marine species; 2) reduction in the potential for ingestion or adsorption of plastics by marine species; 3) reduction in potential impact to marine species from the release of degradation by-products (e.g., release of toxic chemicals), and 4) the long-term reduction in the amount of microplastics produced via fragmentation of macroplastic debris. Consideration must also be given to the possible benefits these plastics have afforded to the same marine species. For example, some species (i.e., flying fish and *Halobates* sp.) are known to lay eggs on floating items (i.e., both natural and anthropogenic); these floating plastics also provide nursery habitat for many fish species. Additionally, rafting species are likely to be impacted more than other fish species as well as bryozoans, hydrozoans, and arthropods (e.g., barnacles, crabs), which use the plastics as habitat in the marine environment.

The ultimate goal of The Ocean Cleanup is to remove plastic debris from the oceans. While the remainder of **Section 5.0** discusses the negative impacts to the biological and social environment resulting from S002 deployment, the potential long-term result of S002 deployment and future plastic collection devices includes substantial beneficial impacts to numerous marine resources. It should be noted that while this EIA addresses lengthy S002 deployment in the NPSG (i.e., up to 24 weeks), it is the long-term goal of The Ocean Cleanup to deploy numerous collection systems in various plastic-polluted ocean basins throughout the world.

Specifically for this EIA, several resources that were screened out of further analysis (**Section 4.1**), would likely benefit from the long-term reduction of floating plastics in the marine system, including: water quality, by reducing chemical-leaching plastics into the water; benthic communities, by reducing the potential for plastics to sink and contaminate or otherwise adversely affect seafloor communities; archaeological resources, by reducing potential for contamination of archaeological sites or shipwrecks; biodiversity, by collectively reducing impacts on the NPSG ecosystem and its species; and recreational resources and tourism, by reducing costs associated with debris removal and negative public perception of coastal or offshore recreational areas contaminated by debris.

Biodiversity was included in the screening process and determined that there is not enough information at this time to fully address biodiversity impacts from the S002. After the up to four, 6 week-long campaigns, data collected during the deployment may be used, if feasible, in conjunction with existing Ecopath models, as well as any additional data from applicable scientific research studies, to develop a model specific for The Ocean Cleanup project. Application of these data within the framework of an Ecopath model may provide another tool to better evaluate any biodiversity impacts from The Ocean Cleanup activities. This information will be included in a Revised Final EIA.

Most biological resources discussed in the subsequent subsections of **Section 5.0** would likely realize some positive benefit from the reduction of plastics on the NPSG, however, the resources that would realize the greatest benefit would be sea turtles, marine mammals, and seabirds; these resources could be subjected to the highest level of potentially harmful effects from floating plastics. **Vulnerable** and **Endangered** populations of sea turtles, marine mammals, and seabirds that are readily affected by entanglement or ingestion of marine debris (including plastics); these three resources would likely reap the greatest benefits as a result of the reduction in the amount of marine plastics in the NPSG. In addition, selective removal of medium to large plastic debris objects may provide a limited degree of protection to coastal habitats where the potential invasion of nonindigenous species is of concern, acknowledging the relatively slow process that this mechanism may entail.

Marine Mammals

According to NOAA (2014a), most cetaceans that become entangled in marine debris do so in actively fished gear. However, numerous examples have been documented of cetaceans becoming entangled in discarded or lost nets, monofilament line, or other abandoned gear. Baleen whale species that have documented entanglements with a definitive cause as marine debris (as opposed to actively fished gear) include humpback, North Pacific right, minke, gray, and bowhead whales (Laist, 1997; Baulch and Perry, 2012). All of these species except the bowhead whale may occur in the NPSG.

It is not possible to estimate the number and species of marine mammals that may be prevented from becoming entangled in marine debris due to its removal by S002. However, it is known that a significant number of marine mammals become entangled. For example, based on scars, Robbins and Mattila (2004) estimated that 46% to 68% of humpback whales have been entangled at some point in their life. Additional discussion of entanglement potential may be found in Stelfox et al. (2016) and Gilman et al. (2021). Given the **Endangered** status of some of the marine mammal species that may be found within the NPSG, if successful at removing plastics and other marine debris, S002 will almost assuredly contribute to a **Beneficial** impact – reducing marine mammal entanglements and deaths caused by discarded rope, nets, monofilament line, and other anthropogenic debris.

Sea Turtles

All species of sea turtles have been documented as entangled with marine debris. Of particular concern in places such as the NPSG, where large amounts of debris have accumulated, is the tendency of juvenile turtles to seek shelter under or within floating objects.

Of the seven extant sea turtle species, five may be found in the NPSG in the vicinity of S002 deployment. Due to trans-Pacific migratory pathways that transect the NPSG (Benson et al., 2011), leatherbacks may be the most likely sea turtle species to be present. However, juvenile loggerheads are also known to occur in the North Pacific (Abecassis et al., 2013). Leatherbacks and loggerheads have both been commonly observed entangled in monofilament line. Other debris that has been documented entangling sea turtles includes plastic six-pack rings, burlap bags, plastic bags, bottles, and other debris (Miller et al., 1995).

Similar to marine mammals, it is not possible to estimate the number and species of sea turtles that may be prevented from becoming entangled in marine debris due to the removal of debris by S002. However, because sea turtles are relatively common (as compared with some species of marine mammals), it is likely that a substantial number have become entangled at some point in their life. A study by Bjorndal and Bolton (1995) documented more than 1,500 free swimming sea turtles and reported that approximately 5% of all turtles were entangled in some type of debris. Regional analyses of turtle entanglements in the north Atlantic and Mediterranean by Darmon et al. (2017) suggested that turtles select areas where debris is more concentrated, whether this occurs because both debris and turtles drift to the same areas due to currents, turtles meet debris accidentally by selecting high food concentration areas, and/or if turtles actively seek out debris, confusing debris for potential prey items. This suggests that if successful at removing plastics and other marine debris, S002 will almost assuredly contribute to a **Beneficial** impact by reducing entanglements and deaths of sea turtles.

Coastal and Marine Birds

Studies between 1962 and 2012 revealed that 59% of seabirds examined had ingested plastics and nearly one third had plastics in their gut (Blastic, 2017). Seabirds, especially those belonging to the Order of Procellariiformes (albatross, petrels and shearwaters, storm petrels, and diving petrels), often mistake floating plastics for food (Blastic). The effects of plastic ingestion on seabirds have become a particular concern due to the frequency of occurrence and emerging evidence of impacts on seabird body condition and transmission of toxic chemicals which could result in changes in mortality and reproduction (Wilcox et al., 2015). The sizes of ingested plastics have been reported to be between 0.5 and 51.5 mm and up to 11.3 cm resulting in reduced gut storage volume resulting in smaller meal sizes and slower growth rate (Blastic).

It is not possible to estimate the number and species of seabirds that may be prevented from ingesting marine debris due to its removal by S002. However, Wilcox et al. (2015) predicted through modeling that plastics ingestion is increasing in seabirds and estimates that it will reach 99% of all species by 2050, but that effective waste management can reduce the threat. Given the **Endangered** status of some of the marine bird species that may be found within the NPSG, if successful at removing plastics and other marine debris, S002 will almost assuredly contribute to a **Beneficial** impact – reducing seabird ingestion and deaths caused by the ingestion of the buildup of toxic chemicals.

Other Resources

Other resources (e.g., fish and fishery resources, protected areas) may also benefit from the removal of plastics and marine debris from the NPSG. Removal of the plastic debris will reduce the potential for entanglement, ingestion, or contamination of, numerous species and ecosystems. Overall, if successful, the result of The Ocean Cleanup project (including both the planned up to 24-week campaigns in the NPSG and future campaigns around the world) will result in plastic and debris removal, a reduction in the extent of negative impacts caused by plastic pollution, and consequently result in a **Beneficial** impact to biological and social resources in the NPSG and within other world oceans.

Plankton and Neuston

The plankton and neuston communities may not benefit from plastics removal as much as for other resources and could have a counter-productive impact on the biodiversity and food-web structure and recruitment of several commercial meroplanktonic species. As discussed above, data collected during the deployment may be used, if feasible, in conjunction with existing Ecopath models, as well as any additional data from applicable scientific research studies, to help better evaluate the impacts to these communities.

Data Collection

Direct collection of scientific data from survey vessels operating in remote areas of ocean is rare due logistical limitations and cost. The deployment of S002 will result in the collection of primary data that may further scientific knowledge about how marine life is attracted to offshore debris and interacts with floating plastic. Reports from PSOs and the monitoring of camera systems onboard project vessels will provide a database (i.e., presence/absence data) for marine mammals and sea turtles from the eastern Pacific. Furthermore, scientific equipment on S002 will also collect a variety of meteorological and hydrographic data, while sampling with bongo nets and manta trawls will acquire data regarding plankton and neuston present in the area. Although difficult to quantify precisely, the collection of scientific data resulting from the deployment of S002 will have a **Beneficial** impact by contributing to the base of scientific knowledge about marine life in the eastern Pacific.

5.2.2 Potential Impacts on Plankton and Neuston

Because potential impacts to plankton and neuston are similar, they are being discussed together in the following section to reduce redundancy.

5.2.2.1 Impact Producing Factor(s)

- S002 – Entanglement/Entrapment
- S002 – Attraction/Ingestion of Plastics
- Noise and Light
- Accidental Fuel Spill

5.2.2.2 S002 – Entanglement/Entrapment

Potential Impacts

Because S002 is an actively towed system, it is likely that zooplankton, phytoplankton, ichthyoplankton, and neuston that have limited or no active mobility will become entrapped within the RZ during deployment in the NPSG. During plastics collection operations, S002 will collect plankton and neuston in the RS (two 400-m wings designed to guide plastics into the RZ). The wings of the RS extend 3 m below the water surface, have a mesh size of 10 mm × 10 mm, and the System opening between the wings will be approximately 500 m. Any plankton or neuston approximately 10 mm or larger that are within the area swept by S002 will likely be retained in the RZ. During plastics extraction operations, S002 will be towed at a slower speed, and the opening between the wings will be reduced to approximately 5 m, which significantly reduces the area swept by the system possibly also reducing the amount of plankton and neuston retained in the RZ.

The ability to estimate potential losses of neuston to S002 is problematic. There is an obvious paucity of data regarding the structure and functioning of the neuston communities in most of the world's oceans, as evidenced by the low number of published journal articles or grey literature. The spatial and temporal distribution of the neuston community in the NPSG will largely depend on the species composition of the community, their different diel and ontogenic migrations, their different life cycles, and life span (i.e., generation times). Spatial distribution of neuston tend to follow mesoscale circulation patterns, temperature, salinity, and wind patterns within the area of interest (Thibault, 2021, personal communication). Additional information regarding neuston density estimates and generation times is presented in the **Appendix**.

One recent effort to sample neuston within the North Pacific has been summarized by Egger et al. (2021), based on neuston collections both within and outside of the NPSG. Egger et al. (2021) report rare observational data on the relative spatio-temporal distribution of floating plastic debris (0.05 to 5 cm in size) and members of the neuston in the eastern North Pacific Ocean. The Egger et al. (2021) study was based on 54 Manta trawl samples collected in the eastern North Pacific Ocean during two expeditions between July 2015 and December 2019. A total of nine Manta trawls were conducted during The Ocean Cleanup's Mega expedition (Lebreton et al., 2018) between July and September 2015, of which six were deployed during daytime and three during nighttime. The Manta trawl, with an aperture of 90 cm × 15 cm and a square mesh net of 500 µm (333 µm mesh size cod-end), was deployed for 60 to 180 minutes at a tow speed of <3 knots. An additional 45 Manta trawls were conducted for 30 minutes at a tow speed of <2.5 knots during The Ocean Cleanup's North Pacific Mission 3 (NPM3) research expedition onboard the M/V *Maersk Transporter* in November/December 2019, including 39 daytime tows and 6 nighttime tows. The longer Manta trawl deployments during the Mega expedition (as compared to the NPM3 expedition) resulted in a lower average detection limit: 114 individual km^{-2} (Mega) vs. 611 individuals km^{-2} (NPM3). Sampled water surfaces were estimated based on distance measurements from a mechanical flow meter multiplied by the width of the net mouth. Observed species and their relative densities within the NPSG, as determined by Egger et al. (2021) in association with floating plastics, are presented in **Table 5-4**. Results presented by Egger et al. (2021), while representing multi-year collections (2015-2019), are limited to a total of 54 tows, several of which were located outside the NPSG.

Previous studies dealing with the quantification of neuston densities in the NPSG are scarce. The most complete effort is by Moore et al. (2001), based on 11 stations sampled along two transects measuring 174 and 85 nmi, although no information on the spatial variation along those two transects was provided. Moore et al. (2001) reported on plankton samples, reporting on abundance and dry weight. Details of the taxonomic composition of each sample were absent; only the filter feeding salp (*Thetys vagina*) was identified. Zooneuston mean abundance was 1,837,342 organisms km^{-2} with a mean mass of 841 g km^{-2} (dry weight), and abundance values ranging from 54,003 to

5,076,403 organism km^{-2}. The authors also highlighted the strong day/night component in the neuston community, noting that zooneuston were at least three times more abundant at night. Other studies in the eastern Pacific were conducted outside of the NPSG (e.g., Moore et al., 2002; Lattin et al., 2004) and mentioned only plastic to plankton ratios in term of biomass.

A conservative estimate of neuston potentially captured by S002 can be calculated by employing a basic area swept model, accounting for the opening dimensions of S002 and varying vessel tow speeds. Several important caveats or limitations to this approach are warranted, the most important of which is that a uniform and constant density of neuston is assumed by the model. Per several sources (e.g., Goldstein et al., 2013; Helm, 2021), neuston exhibit patchy distribution (i.e., they are not uniformly distributed). Neuston blooms/aggregations are common, a fact that cannot be accounted for in a basic area swept model. According to Brandon (2021, personal communication), the blooms or aggregations realized by some drifting neuston species may simply be the result of currents and winds accumulating them in one spot. In contrast, swarms, or blooms, of salps (which may occur both in the neuston and deeper in the water column) are due to a life cycle that allows them to be highly adapted to patchy, unpredictable food sources. When there is little food available, their alternation of generations and hermaphroditism allows them to maintain genetic variability and to exist without reproducing (Alldredge and Madin, 1982). However, when they encounter abundant food sources, their high growth rate, short generation time, high fecundity, direct development, maternal nutrition of both the embryos and the stolons, efficient morphology, and alternation of generations all combine to allow for population explosions (Alldredge and Madin, 1982).

Table 5-4. Estimated density of neuston species in the North Pacific Subtropical Gyre (NPS) and the calculated numbers of individuals potentially collected by S002 per day. Reported densities from Egger et al. (2021) reflect calculated densities found in association with floating plastics (i.e., within the NPSG).

Species/Taxa		Reported Densities (Individuals km^{-2})		Numbers of Individuals Potentially Collected at Different Vessel Speeds (Nominal Mode)					
				@0.5 m s^{-1}		@1.0 m s^{-1}		@1.5 m s^{-1}	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
V. velella	Hydrozoan	557	855	12,512	19,207	25,025	38,413	37,537	57,620
Halobates spp.	Arthropoda	9,429	32,655	211,813	733,562	423,626	1,467,124	635,439	2,200,686
J. janthina	Mollusca	542	4,566	12,175	102,571	24,351	205,141	36,526	307,712
P. porpita	Hydrozoan	91	678	2,044	15,231	4,088	30,461	6,133	45,692
Glaucus spp.	Mollusca	1,000	1,000	22,464	22,464	44,928	44,928	67,392	67,392
P. physalis	Hydrozoan	0	0	0	0	0	0	0	0
Copepods	Arthropoda	43,545	1,731,593	978,195	38,898,505	1,956,390	77,797,010	2,934,585	116,695,515
Amphipods	Arthropoda	643	6,939	14,444	155,878	28,889	311,755	43,333	467,633
Pteropods, isopods, heteropods	Mollusca/Arthropoda	187	4,654	4,201	104,547	8,402	209,095	12,602	313,642
Crabs	Arthropoda	604	3,501	13,568	78,646	27,137	157,293	40,705	235,939
Squid	Mollusca	371	588	8,334	13,209	16,668	26,418	25,002	39,626
Euphausiids, shrimp	Arthropoda	570	25,320	12,804	568,788	25,609	1,137,577	38,413	1,706,365
Fish	Chordata	622	4,949	13,973	111,174	27,945	222,349	41,918	333,523

Other caveats of the area swept model include an inability to assess escapability (i.e., what percentage of the neuston can escape the system) and survivability (i.e., for those neuston species small enough to escape the RZ 10 mm x 10 mm net, what percentage survives). A portion of the neuston community is comprised of a variety of species that are true drifters (see **Section 4.3.2.1;** as opposed to rafting species, see **Section 4.3.2.3**), with their spatial distribution determined by the wind and weather/storm events. For example, *Velella velella* come in two forms – a right-handed and a left-handed orientation, based on which way their sail is oriented. *V. velella* are thought to be equally mixed together in the center of the Pacific. By the time individual *Velella* reach the coasts of Asia or the coast of North America on the edges of the NPSG, one orientation predominates as the wind has determined their distribution (Brandon, 2021, personal communication; Ferrer and González, 2021). Neuston are also found in association with drifting natural and anthropogenic debris (i.e., rafting assemblage), as described in **Section 4.3.2.3**; rafting neuston distribution patterns, while affected in a similar fashion as true drifters, are linked more closely to the transport of the floating plastic debris with which they associate. As a result of these caveats, the area swept model presents a very conservative estimate of densities potentially removed from the ocean surface on a daily basis.

It is necessary, when applying the area swept model, to account for the two different tow configurations to be used by S002. During each of the proposed 1.2 to 2 week-long S002 deployments for plastic collection operations, the majority of the time 8.4 days will be used for plastic collection operations (**Section 2.1.3**), followed by a shorter period one day for plastic extraction from the net (**Section 2.1.4**). During plastic collection, the mouth of S002 will be 520 m; during plastic extraction, the cod end will be removed from S002 and the remainder of the system will be towed with a mouth opening of 5 m. In summary, during a 1.2 week (8.4 day) deployment, plastic collection will occur for 7.4 days (88% of the time), with plastic extraction requiring one day (12% of the time).

Based on the tow speed of S002 during plastic collection and the estimated size of the Great Pacific Garbage Patch of 1,600,000 km^2 (Lebreton et al., 2018; The Ocean Cleanup, 2021), the area swept per day would range from 22.5 km^2 at 1 knot tow speed to 67.4 km^2 at 2.5 knot tow speed, representing between 0.0014% and 0.0042% of the total area of the EPGP. During plastic extraction, the area swept per day would be 0.22 km^2 at 1 knot tow speed.

Neuston densities adapted from Egger et al. (2021) are presented in **Table 5-4** along with the associated number of individuals that could be collected per day at different tow speeds during plastic collection, with acknowledgement of the area swept model limitations noted previously. During plastic extraction, the reduced mouth size of the system (i.e., 5 m) will collect ~10% fewer neuston. Since S002 is actively towed, any plankton or neuston that become trapped in the RZ are unlikely to be able to free themselves and will remain trapped until opening of the RZ during plastic collection approximately every 1.2 to 2 weeks.

As discussed in **Section 4.3.2**, the marine neuston community is diverse and includes a variety of organisms with different life histories. For the purposes of identifying impacts attributed to entanglement/entrapment, both neuston defined by location (i.e., epineuston, hyponeuston, and metaneuston or exoneuston) or life stage (i.e., euhyponeuston, planktohyponeuston, and merohyponeuston or endohyponeuston) may all be impacted based on their (at least partial) interaction with the surface or near surface waters. Some of these groups (e.g., the planktohyponeuston, which vertically migrate) may be impacted to a lesser degree by entanglement and entrapment than others because they will be present at the surface near the RS and RZ less often. Conversely, neuston that live solely near the surface or just beneath the surface (such epineuston and hyponeuston) may be disproportionally impacted to a higher degree.

Based on the fragile, often gelatinous nature of much of the oceanic neuston, they are easily damaged. Any entrapment of these organisms will likely result in them being compacted or compressed against the mesh in the RS or RZ, with subsequent mortality. Upon retrieval of the S002 net, collected biota would likely be an amorphous biotic "soup" with only a negligible portion of live organisms and only the largest obvious ones, like *Porpita* and *Velella*, to be accounted for by visual observation as stated in Ferrari (2019). Biofouling of the RS and RZ mesh over time could increase clogging and will reduce the filtering efficiency of the net, which would likely increase impacts to the smallest entrapped organisms.

Sweeping activities might increase the entanglement of the neuston species, mostly crustaceans such as decapod larvae, and copepods which carry large spines, protruding growths, and/or complex feather-like structures which can easily be caught in fibers (Kang et al., 2020).

The environmental monitoring activity performed during The Ocean Cleanup's deployment of System 001/B in the NPSG in 2019, reported an estimated 500 colonies of the gelatinous hydrozoan *Velella velella* collected in the system as bycatch, confirming their possible presence in the NPSG during the collection period. One other species of gelatinous macrozooplankton was identified during the 2019 campaign (Violet sea snail; *Janthina janthina*); however, the degraded nature of the shells did not allow for an estimate of the number of snails. Due to their gelatinous nature, many organisms collected within the RS or RZ will likely be unable to escape. It is important to note that System 001B, as tested in the NPSG in 2019, was a fundamentally different design which functioned by herding floating macroplastics using a barrier system, whereas S002 will utilize a mesh net.

Rafting neuston, including species found in association with floating debris, may be at particular risk from entanglement and entrapment given that the removal of floating debris is the primary purpose of S002. Given the relatively high density of plastics and floating debris within the NPSG, there is likely a substantial rafting neuston community within the area where S002 will be deployed. Rafting materials are frequently dominated by three lepadomorph barnacle species – *L. anatife*ra, *L. pacifica*, and *L. (Dosima) fascicularis*. If these or other rafting species are attached to debris collected by the RS or RZ, they will likely suffer mortality while in the RZ or when they are removed from the water during plastic collection.

The long-term impacts of the deployment of S002 should be **Beneficial** on plankton and neuston due to the removal of large amounts of plastics and other marine debris from the NPSG. This will result in a reduction in the potential for plankton and neuston to ingest plastics, and a reduction in potential impacts from release of degradation by-products (e.g., release of toxic chemicals).

The short term, and possibly long-term impacts of S002 on plankton and neuston are expected to be negative. Because of the probable mortality of a substantial number of plankton and neuston organisms from S002 deployment, impact intensity is rated as moderate, although it is possible that impact intensity could be high. The extent of impact is expected to range from local to regional, with a short-term duration (based on relatively short generation times). Resulting impact consequence is deemed moderate. Due to the likely nature of this impact, the overall impact significance rating is **3 – Medium** during plastic collection operations prior to implementation of mitigation measures. In the event high impact intensity occurs, with extent ranging from local to regional, and duration being long-term, impact consequence would be severe and overall impact significance would be **4 – High**.

During plastics extraction operations the S002 is towed by one vessel, at a slower speed, and has a narrowed wingspan (approximately 5 m) which significantly reduces the area swept by the system. Plastics extraction operations are anticipated to take 12 hrs for each extraction and will occur approximately 5 times during the first 6-week campaign and less often during the subsequent

6-week campaigns. While the impact likelihood would remain the same, the impact intensity would be reduced due to a smaller area for capture; resulting in an overall impact significance of **2 – Low** during plastic extraction operations prior to implementation of mitigation measures.

Mitigation Measures

The Ocean Cleanup will implement several mitigation measures to help reduce potential impacts to plankton and neuston from entrapment and entanglement. This mitigation measure includes the following:

- **Inclusion of an escape aid** – S002 will be equipped with a remote triggered quick release for the cod end of the RZ to free potential clogs[9]; and
- **Net resting** – the net will be allowed to rest prior to retrieval to give live swimming organisms time to escape.

Mitigation measure effectiveness will be affected if the cod end of System 002 becomes severely clogged. Even if a quick release is put in place, few organisms will survive after being compacted in the RZ. Zooplankton will mostly be entangled within the mesh system and will have little to no ability to swim away from the net even if deployed at low speed.

Residual Impacts

The mitigation measure that The Ocean Cleanup will implement during plastics collection operations should reduce two components of impact consequence, impact intensity and likelihood. The escape aid may reduce impacts to some species, but generally the reduction in impacts is not significant enough to warrant a reduction in the impact significance and would remain **3 – Medium** to **4 – High**.

For entanglement and entrapment, all mitigation measures would still be in place during plastics extraction operations other than the remote quick release. Therefore, the mitigation measures reduce the impact intensity from high to moderate and also somewhat reduce the likelihood of impact occurrence, resulting in a reduction of impact significance to **2 – Low** for plastic extraction operations.

5.2.2.3 S002 – Attraction/Ingestion of Plastics

Potential Impacts

As detailed in **Section 4.3.2**, the neuston of the NPSG is comprised of free-floating species, ichthyoplankton, and a rafting assemblage. While floating plastic debris naturally attracts rafting assemblage species, free-floating and ichthyoplankton may or may not be found in association with macroplastics. Deployment of S002, including during active collection (net collection) and extraction (net emptying) phases (see **Sections 2.1.3** and **2.1.4**), is not expected to attract neuston, primarily because the system will be constantly moving while under tow.

The potential for planktonic filter feeders and other neuston to accidentally ingest plastic particles, or to have additives from plastics adsorbed to their tissue, will be heightened in the vicinity of S002 due to the increased density of plastic particles collected by the system. Copepods will not be able to ingest microplastic but may ingest nanoplastic (i.e., prey size for most copepod species is 10 µm to

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[9] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

150 µm). Macrozooplankton passive filter feeders like pelagic tunicates (salps, doliolids) and molluscs (via deployment of a mucus web) are more likely to ingest microparticles.

Moore et al. (2001) completed plankton tows in the NPSG and reported that plankton abundance was five times higher than plastic abundance, but the mass of plastic was higher than the plankton mass in most samples, though this was skewed by a few large pieces of plastic. The high amount of plastics relative to plankton indicates that the chance ingestion of plastic by filter feeders is common, particularly for microplastics. Due to their size relative to neuston, macroplastics are less likely to be ingested. Given the relatively high concentration of plastic particles in the NPSG in the area of S002 deployment, it is likely that the deployment will result in an increased level of plastic ingestion or adsorption by plankton and neuston. Thibault (2021) also notes that potential ingestion of macro- and microplastics by filter feeding neuston needs to account for particle size distribution, the latter of which Moore et al. (2001) did not address.

Goldstein (2012) suggests that plastic-associated rafting organisms may be affecting the pelagic ecosystem by reworking the particle size spectrum through ingestion and egestion (also see Mook, 1981). Suspension-feeding rafting organisms prey on a variety of particle sizes, from 3 µm to 5 µm for *Mytilus* mussels (Lesser et al., 1992), 10 µm to 20 µm for bryozoans (Pratt, 2008), 20 µm to 125 µm for caprellid amphipods (Caine, 1977), and 0.5 mm to >1 mm for lepadid barnacles and hydroids (Evans, 1958; Boero et al., 2007). This size range encompasses a significant portion of the non-microbial particle size spectrum of the oligotrophic North Pacific (Sheldon et al., 1972). Because particle size determines which energy pathway benefits – either the microbial loop or the metazoan food web, Karl et al. (2001) noted that any large-scale alterations in particle size could substantially influence the species composition of the NPSG. The food web dynamics for neuston need to be clearly characterized (Thibault, 2021). Copepods are omnivorous and will prey upon ciliates and flagellates as part of the microbial loop. Euphausiids can also prey on members of the microbial food web. Salps and doliolids can feed on bacteria and cyanobacteria. Karl et al. (2001) did not account for gelatinous zooplankton, as this component of the neuston was not well defined and were not included in their food web characterization; the capacity for gelatinous zooplankton to feed on very small items (via filter feeding) or larger items will strongly modulate the transfer of energy through the food web (Thibault, 2021).

The increased ingestion of plastics by filter feeders as a result of S002 is a localized, temporary impact, offset to a limited extent by the long-term **Beneficial** impact of the deployment and associated removal of plastics from the NPSG. Ingestion of plastics or adsorbtion of plastic-linked chemicals by plankton and neuston as a result of deployment of S002 is considered a likely impact, although of minor consequence and severity. Overall impact significance is rated **2 – Low**. The likelihood and impact significance of those ingested plastics and chemicals being bioaccumulated through the food chain through the ingestion of these plankton organisms is very difficult to quantify.

Mitigation Measures

No mitigation measures are recommended to avoid ingestion of plastic particles by plankton and neuston.

Residual Impacts

The residual impact significance remains **2 – Low**.

5.2.2.4 Noise and Lights

Potential Impacts

Plankton and neuston that have limited active mobility may be attracted to the system due to lights on the vessel or the system itself. Conversely, there is some evidence that both natural and anthropogenic light pollution may suppress diel migration of zooplankton, which would reduce the number of organisms migrating into the surface layer (Ludvigsen et al., 2018). S002 and its tow vessels will stand out in the project area as possibly the only artificial light sources.

Attraction of plankton and neuston to lighting from the system and tow vessels would be limited to the immediate vicinity of the system and vessels. However, it could result in increased predation by fishes or other predators who are similarly attracted to the noise and lights of the system. Many plankton and neuston are free floating and thus impacts would mostly only be applicable to those species that could actively move towards the system itself (e.g., planktohyponeuston which vertically migrate) or free floating plankton and neuston that happen to be in the vicinity.

Impacts on plankton and neuston from noise and lights is considered likely, though with a minor impact consequence. Overall impact significance is rated **2 – Low**.

Mitigation Measures

The Ocean Cleanup will implement one mitigation measure to help reduce potential impacts to plankton and neuston from noise and lights. This mitigation measure includes the following:

- **Limit lighting** – To the extent practicable, the vessel will be blacked out at night to avoid attracting species that undergo diel vertical migrations. Navigational lights on the system will flash intermittently to reduce shining light on the water at night.

Residual Impacts

While limiting lighting will reduce the likelihood of impacts, the reduction is not significant enough to warrant a reduction in the impact significance. The residual impact significance remains **2 – Low**.

5.2.2.5 Accidental Fuel Spill

Potential Impacts

A diesel fuel spill could affect plankton and neuston because they do not have the ability to avoid contact. Many planktonic communities drift with water currents and recolonize from adjacent areas. Because of these attributes and their short life cycles, plankton usually recover rapidly to normal population levels following disturbances. Eggs and larvae of fishes will suffer mortality if exposed to certain toxic fractions of diesel fuel, but due to the wide dispersal of early life history stages of fishes, a diesel fuel release would not be expected to have significant impacts at the population level. Little is known about the impacts of a fuel spill on neuston groups, but in the event of a diesel spill, the area affected would be relatively small and the duration of impact would presumably be only a few days.

Due to the limited areal extent and short duration of water quality impacts, a small diesel fuel spill would be unlikely (rare) to produce significant impacts on plankton and neuston, and any impacts that do occur would be of negligible consequence. Overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to plankton and neuston from an accidental fuel spill. These mitigation measures include the following:

- **Shipboard Oil Pollution Emergency Plan (SOPEP)** – Contractor will ensure that a SOPEP is in place on the towing, monitoring, and debris collection vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained.

- **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.

- **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings.

- **No re-fueling at sea** – No re-fueling will occur at sea.

- **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impacts would be reduced however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.2.6 *Plankton and Neuston Impact Summary*

<u>*Impact Rating*</u>

Impact	Intensity	Extent	Duration	Consequence	Likelihood	Impact Significance
Removal of plastics and debris from the environment	The plankton and neuston communities may not benefit from plastics removal as much as for other resources and could have a counter-productive impact on the biodiversity and food-web structure and recruitment of several commercial meroplanktonic species. As discussed above, data collected during the deployment may be used, if feasible, as well as any additional data from applicable scientific research studies, to help better evaluate the impacts to these communities.					
Entanglement in S002 or accumulated debris resulting in injury or death during both plastics collection operations and plastics extraction operations	Moderate to High	Local to Regional	Short Term or Long Term	Minor or Moderate	Likely	2 – Low to 4 – High
Attraction to S002; ingestion of congregated plastics resulting in injury or death	Moderate	Immediate Vicinity	Short Term	Minor	Likely	2 – Low
Behavioral modification changes (e.g., suppress diel migration, attraction to system) from light	Moderate	Immediate Vicinity	Short Term	Minor	Likely	2 – Low
Diesel fuel exposure, including ingestion	Low	Immediate Vicinity	Short Term	Negligible	Rare	1 – Negligible

Mitigation Measures

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Entanglement in S002 or accumulated debris resulting in injury or death during both plastics collection operations and plastics extraction operations	• **Escape aids** – System equipped with a remote triggered quick release for the end of the Retention Zone to free potential clogs[10]; and • **Net resting** – the net will be allowed to rest 30 to 60 minutes prior to retrieval to give some species time to escape.	Reduces Intensity and Likelihood	2 – Low* 4 – High*
Attraction to S002; ingestion of congregated plastics resulting in injury or death	• None recommended.	None	2 – Low
Behavioral modification changes (e.g., suppress diel migration, attraction to system) from light	• **Limit lighting** – Lights will be limited at night to the extent practicable to avoid attracting species that undergo diel vertical migrations. Navigational lights on the system will flash intermittently o reduce shining light on the water at night.	Reduces Likelihood	2 – Low
Diesel fuel exposure, including ingestion	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – Contractor will ensure that a SOPEP is in place on towing, monitoring, and debris collection vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels. • **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings. • **No re-fueling at sea** – No re-fueling will occur at sea. • **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.	Reduces Likelihood	1 – Negligible

* = The escape aids may reduce impacts to some species, but generally the increase is not significant enough to warrant a reduction in the impact significance without additional research.

[10] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

5.2.3 Potential Impacts on Fish and Fishery Resources

5.2.3.1 Impact Producing Factor(s)

- S002 – Entanglement/Entrapment
- S002 – Attraction/Ingestion of Plastics
- Vessel – Physical Presence/Strikes
- Noise and Lights
- Accidental Fuel Spill

For fish and fishery resources, the impacts of entanglement/entrapment, attraction/ingestion of plastics, and vessel physical presence/strikes are interrelated. Therefore, potential impacts from these three IPFs will be discussed together to avoid redundancy.

5.2.3.2 S002 – Entanglement and Entrapment, Attraction/Ingestion of Plastics, and Vessel – Physical Presence/Strikes

Potential Impacts

Fish species are attracted to offshore structures such as oil and gas platforms and various types of flotsam (Shomura and Matsumoto, 1982; Franks, 2000; Fabi et al., 2004;). These structures can provide substrate habitat for invertebrates, protective habitat for finfish, and lighting. Studies have shown that different fish species have different utilization patterns of offshore structures which may be influenced by physical factors such as temporal variation in temperature and oceanographic conditions as well as biological factors such as prey availability, species-specific sedentary/migratory behavior, and life cycle stages of individuals (e.g., Stanley and Wilson, 1991; Schroeder and Love, 2004; Love et al., 2005; Love et al., 2006; Page et al., 2007; Fujii, 2016; Fujii and Jamieson, 2016). S002 and tow vessels, as floating structures in an open-ocean environment, will likely act as fish aggregating devices (FAD). In oceanic waters, the FAD effect would be most pronounced for epipelagic fishes such as tunas, dolphin, billfishes, and jacks, which are commonly attracted to fixed and drifting surface structures (Holland, 1990; Higashi, 1994, Relini et al., 1994). The FAD effect could possibly enhance the feeding of epipelagic predators by attracting and concentrating smaller fish species.

There are also numerous flotsam-associated species that may either be attracted to the vessels or System, or be present within the floating debris itself. Numerous species of fishes are attracted to offshore flotsam, likely in search of shelter and food. The most common flotsam-associated species are the jacks and triggerfish, but over 300 species have been identified to be associated with offshore debris (Castro et al., 2002).

Plastic debris accumulating in the marine environment is known to fragment into smaller pieces, which increases the potential for ingestion by smaller marine organisms (Ryan et al., 2009). Additionally, the buoyancy of smaller pieces of plastic increases the likelihood for mixing with surface food sources. Once attracted to the S002, fish and fishery resources will have a greater chance of ingesting plastics that have accumulated in the NPSG through either direct feeding on the plastic or by consuming lower trophic level organisms that have fed on plastics. Studies have shown a wide variety of fishes with plastics in their guts including planktivorous fish to larger predatory species, migratory and non-migratory species, and species inhabiting various depth ranges (Ryan et al., 2009; Boerger et al., 2010; Davison and Asch, 2011; Carson, 2013; Choy and Drazen, 2013; Choy et al., 2013; Gassel et al., 2013; Rochman et al., 2014;). The ingestion of plastics can affect fish in a variety of different ways (**Figure 5-2**) including impacts to the immune system of the fish, both chemically (through the absorption of toxic components) and physically by obstructing the digestive system (Espinosa et al., 2016).

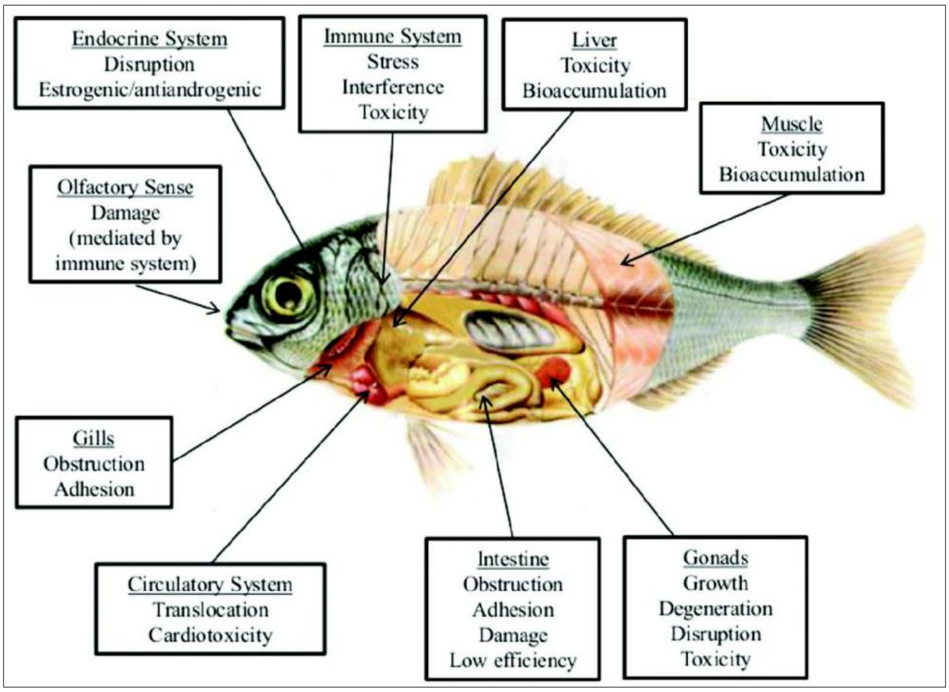

Figure 5-2. The principal effects of microplastics on fish (From: Espinosa et al., 2016).

Plastics collection and extraction operations may result in the capture, injury, or death of substantial numbers of individual fishes by S002. However, it is not expected that the number of potentially impacted fishes will be significant on the regional or population level for any species. During The Ocean Cleanup's deployment of System 001B in the NPSG in 2019, a total of 11 species of fish were observed in proximity to the deployed system, including: blue shark, dolphinfish, California flying fish, blue marlin ocean sunfish, pilotfish, striped marlin, Pacific sergeant major, chubs, and yellow-tail amberjack (The Ocean Cleanup, 2020). Additionally, unidentified tuna, sharks, pufferfishes, and other unidentified large and small fishes were observed. No large pelagic fish were caught as bycatch during the 2019 NPSG campaign. Although a direct comparison cannot be made between the two different systems, S001B and S002, since the designs and operations are different, the data from the 2019 campaign provides some insight to the species that may be attracted to the S002.

During a field test of a prototype of 002 in the North Sea in 2020, after each tow there were numerous small herring and other small fish entangled (and mostly deceased) within the system's RZ mesh. No large, pelagic fish were observed as bycatch. For S002 deployment in the NPSG, a similar type of bycatch of small fishes is expected, but few or no large pelagic fishes are expected to be caught due to their typically robust swimming abilities and the slow tow speeds (0.5 to 2.5 knots). Schools of smaller fish are more likely to congregate within the system for shelter and search for food, and then be unable to escape the RS and RZ.

The long-term impacts of the deployment of S002 should be **Beneficial** on fish and fishery resources due to the removal of large amounts of plastics and other marine debris from the NPSG. This will result in a reduction in the potential for fish to ingest plastics, and a reduction in potential impacts from release of degradation by-products (e.g., release of toxic chemicals).

Vessel strikes are not expected to occur to fish and fishery resources. Effects on fish and fishery resources from attraction/ingestion of plastics and from vessel physical presence are considered likely, and expected to be of moderate intensity, short term, and of minor consequence resulting in an impact significance of **2 – Low**. No population-level effects on fish communities would be expected. However, because of the high likelihood and high impact intensity of fish and fishery resources becoming entangled/entrapped in the RZ, impact consequence for this IPF is moderate, resulting in an impact significance of **3 – Medium** during plastic collection operations.

During plastics extraction operations the S002 is towed by one vessel, at a slower speed, and has a narrowed wingspan (approximately 5 m) which significantly reduces the area swept by the system. Plastics extraction operations are anticipated to take 12 hrs for each extraction and will occur approximately 5 times during the first 6-week campaign and less often during the subsequent 6-week campaigns. While the impact likelihood would remain the same, the impact intensity would be reduced due to a smaller area for capture; resulting in an overall impact significance of **2 – Low** during plastic extraction operations prior to implementation of mitigation measures.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to fish and fishery resources from entanglement/entrapment, attraction to S002 and subsequent ingestion of plastics, and from attraction to the tow vessels. These mitigation measures include the following:

- **Visual cues –** Use of light colored netting to increase visual detectability for the wings and RZ, with darker yellow netting used for escape routes and the use of white flashing LED lights to enhance detectability of the system.

- **Vessel operations –** Towing vessels in the NPSG will travel as extremely slow speeds (0.5 to 2.5 knots).

- **Escape aids –** System equipped with a remote triggered quick release for the end of the RZ to free where necessary entangled fish[11]; the net will be allowed to rest prior to retrieval to give fish time to escape.

- **Visual monitoring** – Monitoring during the project will identify fish that may enter the S002:
    - Use of one forward- and one backwards-looking Thermal/RGB camera system; and
    - Multiple above and underwater cameras will be installed above and inside the retention zone.

Residual Impacts

The mitigation measures for attraction to the system and attraction to the vessel will somewhat reduce the likelihood of impacts from these factors, but the residual impact significances will remain **2 – Low** for both plastic collection and extraction operations. For entanglement and entrapment, the mitigation measures reduce the impact intensity from high to moderate and also somewhat reduce the likelihood of impact occurrence, resulting in a reduction of impact significance to **2 – Low** for plastic collection operations.

For entanglement and entrapment, all mitigation measures would still be in place during plastics extraction operations other than the remote quick release. Therefore, the mitigation measures

[11] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

reduce the impact intensity from high to moderate and also somewhat reduce the likelihood of impact occurrence, resulting in a reduction of impact significance to **2 – Low** for plastic collection operations.

5.2.3.3 Noise and Lights

<u>*Potential Impacts*</u>

Fishes inhabiting or transiting the project area could be subjected to noise from support vessel traffic for the S002. Two support vessels will be present at all times during plastics collection and extraction operations. Vessels cause a path of physical disturbance in the water that could affect the behavior of certain fish species, depending on the type of vessel and ecology of the fish species.

Vessel noise is a combination of narrow-band (tonal) and broadband sound (Richardson et al., 1995). Tones typically dominate up to approximately 50 Hz, whereas broadband sounds may extend to 100 kHz. Usually, the larger the vessel or the faster the vessel is moving, the greater the noise generated (Richardson et al., 1995). Depending on the vessel, source levels can range from less than 150 decibels (dB) to over 190 dB (Richardson et al., 1995). Noise levels from vessels and equipment are within the general hearing reception range of most fishes (Amoser et al., 2004). Engines from the vessels may radiate considerable levels of noise underwater that may contribute significantly to the low-frequency spectrum. Machinery necessary to drive and operate a ship produces vibration within the frequency range of 10 Hz to 1.5 kHz resulting in the radiation of pressure waves from the hull (Mitson and Knudsen, 2003). In addition to broadband propeller noise, there is a phenomenon known as "singing," when a discrete tone is produced by the propeller which can result in very high tone levels within the frequency range of fish hearing.

Vessel noise may disturb pelagic fish and alter their behavior by inducing avoidance, potentially displacing them from preferred habitat, alter swimming speed and direction, and alter schooling behavior (Sarà et al., 2007). Pressure waves from vessel hulls could displace fish near the surface and cause injury or mortality to non-swimming and weakly swimming fish life stages and fish prey. Cavitation of bubbles generated by vessel hull structures and vibrations from vessel pumps could result in barotraumatic injury and mortality of epipelagic non-swimming and weakly swimming fish life stages and fish prey (Hawkins and Popper, 2012). Additionally, vessel noise can mask sounds that affect communication between fishes (Purser and Radford, 2011).

Fish may exhibit avoidance behavior when subjected to loud noises from a vessel. Abnormal fish activity may continue for some time as the vessel travels away. However, vessel noise is inherently transient, rendering adverse impacts temporary. Fish in the immediate vicinity of vessels may also exercise avoidance. Although vessel and equipment noise would increase in project area, negative effects on fish behavior are considered occasional, however, they are expected to be short term and only within the immediate vicinity. For these reasons, the impacts of vessel noise on fish and fisheries resources are of negligible consequence and expected to have an impact significance of **1 – Negligible** for noise.

In addition, S002 will introduce new hard substrate that could provide habitat for some prey species, which subsequently could attract managed species in the upper water column (Fujii, 2015) and at night the operational lights create a small "halo" of light in the water that attracts fish and predators (Barker, 2016). S002 and its tow vessels will stand out in the project area as possibly the only artificial light sources. Lights will be used during evening and night hours on S002 and tow vessels, although efforts will be made to reduce lighting as much as practicable. Fishes may be attracted by the system's nighttime light field. The light may also attract phototaxic prey and provides an enhanced lighting conditions for predators to locate and capture prey while foraging within the light-field surrounding the structure or vessels. Fish foraging in the light field may also attract larger predators, rendering each in turn vulnerable to other predators and also to entanglement and entrapment by the system itself. However, the light-field produced by S002 and associated vessels is expected to cover a significantly smaller area than what is produced by a typical offshore structure such as an oil and gas platform. Additionally, the light field will move as the system is towed and no one location will receive a steady light field. Therefore, the impacts from light are expected to be of moderate intensity, short term, and of minor consequence, resulting in an impact significance of **2 – Low**.

Mitigation Measures

The Ocean Cleanup will implement several mitigation measures to help reduce potential impacts to fish and fishery resources from noise and lights. These mitigation measures include the following:

- **Limit lighting** – To the extent practicable blackout of vessel at night. Navigational lights on the system will flash intermittently to reduce shining light in the water at night.

- **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. The sound generated by banana pingers is localized and will not propagate far and is well above hearing ranges of fish.

Residual Impacts

The elimination of unnecessary acoustic energy mitigation measure will reduce both intensity and likelihood of impacts from noise, but not to the extent to lower the impact significance, which remains **1 – Negligible** for noise.

The mitigation measure of limiting the lighting to the extent practicable will reduce the likelihood of impacts to fish, but not to the extent to lower the impact significance, which will remain **2 – Low** for light.

5.2.3.4 Accidental Fuel Spill

Potential Impacts

A small diesel fuel spill in offshore waters would produce a thin slick on the water surface and introduce concentrations of petroleum hydrocarbons and their degradation products. The extent and persistence of impacts would depend on the meteorological and oceanographic conditions at the time and the effectiveness of spill response measures. Adult and juvenile fishes may actively avoid an accidental fuel spill. Moreover, in the event of a diesel fuel spill, the area affected would be relatively small, and the duration of impact would presumably be only a few days.

Due to the limited areal extent and short duration of water quality impacts, a small diesel fuel spill would be unlikely to produce significant impacts on fish and fishery resources. The likelihood of impacts to fish and fishery resource is considered rare and of negligible consequence severity. Overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to fish and fishery resources from an accidental fuel spill. These mitigation measures include the following:

- **Shipboard Oil Pollution Emergency Plan (SOPEP)** – Contractor will ensure that a SOPEP is in place on towing, monitoring, and debris collection vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained.

- **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.

- **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings.

- **No re-fueling at sea** – No re-fueling will occur at sea.

- **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impacts would be reduced however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.3.5 *Fish and Fisheries Impact Summary*

Impact Rating

Impact	Intensity	Extent	Duration	Consequence	Likelihood	Impact Significance
Removal of plastics and debris from the environment	Removal plastics and other marine debris (i.e., ghost nets) from the NPSG will result in the long-term reduction in the potential impact of fish entanglement; the potential for fish to ingest plastics; and for fish to be impacted by the release of degradation by-products (e.g., release of toxic chemicals); however, the beneficial aspect will be somewhat offset through the removal of nursery habitat for some species of fish.					
Entanglement or entrapment with deployed S002	High	Immediate Vicinity	Short Term	Moderate	Likely	3 – Medium
Attraction to S002 and ingestion of plastics collected	Moderate	Immediate Vicinity	Short Term	Minor	Likely	2 – Low
Attraction to vessels and strike resulting in injury or death	Low	Immediate Vicinity	Short Term	Minor	Remote	1 – Negligible
Behavioral modification changes (e.g., evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels)	Low	Immediate Vicinity	Short Term	Negligible	Occasional	1 – Negligible
Attraction to tow vessels and lights	Moderate	Immediate Vicinity	Short Term	Minor	Likely	2 – Low
Diesel fuel exposure, including ingestion	Low	Immediate Vicinity	Short Term	Negligible	Rare	1 – Negligible

Mitigation Measures

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Entanglement or entrapment with deployed S002	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ with darker yellow netting used for escape routes and use of white flashing LED lights to enhance detectability of the System. • **Vessel operations** – Towing vessels in the NPSG will travel as extremely slow speeds (0.5-2.5 knots). • **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled fish[12]; the net will be allowed to rest 30 to 60 minutes prior to retrieval to give fish time to escape; use of a Fyke Opening just after the entrance to the Retention Area. • **Visual monitoring** – Monitoring during the project will identify fish that may enter the S002: ○ Use of one forward- and one backwards-looking Thermal/RGB camera system; and ○ Multiple above and underwater cameras will be installed above and inside the retention zone.	Reduces Intensity and Likelihood	2 – Low
Attraction to S002 and ingestion of plastics collected	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.	Reduces Likelihood	2 – Low
Attraction to vessels and strike resulting in injury or death	• **None recommended**	None	1 – Negligible
Behavioral modification changes (e.g., evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (vessels)	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. The sound generated by banana pingers is localized and is well above hearing ranges of fish.	Reduces Intensity and Likelihood	1 – Negligible
Attraction to vessels and lights	• **Limit lighting** – Lights will be limited at night to the extent practicable. Navigational lights on the system will flash intermittently to reduce shining light in the water at night.	Reduces Likelihood	2 – Low

[12] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Diesel fuel exposure, including ingestion	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – Contractor will ensure that a SOPEP is in place on towing, monitoring, and debris collection vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels. • **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings. • **No re-fueling at sea** – No re-fueling will occur at sea. • **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.	Reduces Likelihood	1 – Negligible

5.2.4 Potential Impacts on Marine Mammals

5.2.4.1 Impact Producing Factor(s)

- S002 – Entanglement/Entrapment
- S002 – Attraction/Ingestion of Plastics
- Vessel – Physical Presence/Strikes
- Noise and Lights
- Loss of Debris
- Accidental Fuel Spill

5.2.4.2 S002 – Entanglement/Entrapment

Potential Impacts

There is a risk of entanglement any time gear, particularly lines and cables, are put in the water. Gall and Thompson (2015) reviewed previous literature and reported that 52 species of marine mammals have reported entanglement records with marine debris, the majority of which were caused by fishing gear or nets. Allen and Angliss (2011) estimate there are a minimum of 3.3 gray whale mortalities per year along the U.S. west coast attributed to fishing gear entanglement.

In 2016, 71 separate cases of entangled whales were reported off the west coast of the United States. Humpback whales were the predominant species reported as entangled (54 of the 71 cases in 2016). Other identified entangled species included gray whales, blue whales, killer whales, and fin whales. Entanglement cases were associated with specific fishing gear type from the Dungeness crab commercial trap fishery, gillnet fisheries, spot prawn trap fishery, sablefish trap fisher, Dungeness crab recreational trap fishery, and the spiny lobster fishery (NOAA, 2017b).

Stelfox et al. (2016) conducted a literature review of the effect that ghost gear entanglement on marine megafauna, namely mammals, reptiles and elasmobranchs. They reviewed 76 publications and other sources of grey literature were assessed that highlighted that individuals from 40 different species were recorded as entangled in, or associated with, ghost gear from the Atlantic, Pacific, and Indian Ocean basins. Overall, 27 marine mammal species, seven reptile species, and six elasmobranch species were identified as having been reported as entangled in ghost gear, with marine mammals making up the majority of all entanglements (70%). Ghost gear responsible for the entanglements included ghost fishing nets, monofilament lines, ropes from traps and pots, unknown ropes, or a combination of net and line.

Species recorded as entangled in the review by Stelfox et al. (2016) that could be present within the study area include the Guadalupe and Northern fur seals, the California sea lions, Northern elephant seals, Harbor Seals, Gray, Humpback, Sei, and Sperm Whales.

Porpoise and other small cetacean mortality from gillnet entanglement has been documented by Tregenza et al. (1997). Entanglement data for mysticetes may reflect a high interaction rate with active fishing gear rather than with discarded trash and debris (Laist, 1996). Entanglement records for odontocetes that are not clearly related to bycatch in active fisheries are almost absent (Laist, 1996).

S002 consists of nets, lines, and chains that and could potentially entangle marine mammals; however, the system will move slowly during deployment and therefore the likelihood of entanglement is remote as marine mammals may be able to visually identify the S002 and actively avoid contact. Entanglement in marine plastics or other debris that have concentrated within the S002 is more likely; however, still rare, especially as marine mammals may become attracted to the structure and cover that the S002 provides and some marine mammals may mistake congregated plastics as a food source.

By design, the S002 is expected to accumulate marine debris, which may include lines, nets, and other materials that have the potential to entangle marine mammals. However, during plastics collection operations the likelihood of a marine mammal becoming entangled is considered remote, partially due to the relatively small size of the S002 as compared to the NPSG and the North Pacific and the relatively low density of marine mammals. If a marine mammal did become entangled in lines or chains connected to the S002 or in marine debris, nets, or lines accumulated within the S002, the individual could be harmed or drown if it were unable to untangle itself and result in an impact of high intensity. In the case of the death of an endangered marine mammal (such as the North Pacific Right Whale), such an incident could be significant at the population level to that species with a regional extent. It should be noted that while possible, the death of a marine mammal due to the deployment of the S002 is considered remote and that overall, the long-term impacts of the S002 on marine mammals should be **Beneficial** due to the removal of large amounts of plastics and other marine debris from the NPSG. However, because of the possibility of harm or death of marine mammals due to the S002 deployment, the consequence severity is rated moderate. Overall, the remote likelihood and the moderate consequence severity result in an overall impact significance rating of **2 – Low** during plastics collection operations**.**

During plastics extraction operations the S002 is towed by one vessel, at a slower speed, and has a narrowed wingspan (approximately 5 m) which significantly reduces the area swept by the system. Plastics extraction operations are anticipated to take a maximum of 12 hrs for each extraction and will occur approximately 5 times during the first 6-week campaign and less often during the subsequent 6-week campaigns. The impact likelihood would remain remote, the impact intensity would be reduced due to a smaller area for capture, and the impact consequence would remain moderate, resulting in an overall impact significance of **2 – Low** during plastic extraction operations prior to implementation of mitigation measures.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to marine mammal entanglement. These mitigation measures include the following for plastics collection operations:

- **Visual monitoring** – Monitoring during the project will identify marine mammals that may be near tow vessels with:
    - PSOs and use from the vessel of one forward- and one backwards-looking Thermal/RGB camera system; and
    - Multiple above and underwater cameras will be installed above and inside the RZ.
- **Visual cues** – Use of colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.
- **Acoustic deterrent** – Banana pingers attached to the system to deter approach of marine mammals.

- **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled marine mammals[13] and the net will be allowed to rest prior to retrieval to give marine mammals time to escape.

- **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 20 cm to guarantee access to air for marine mammals.

- **Rescue of animals** - Rescue attempts of entangled marine mammals in distress may be attempted according to the Environmental Management Plan.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement during plastics collection operations and the short-term nature of the activities, two components of impact consequence, intensity and likelihood, would be reduced resulting in a residual impact significance of **1 – Negligible** for non-protected species for plastics collection operations. However, for protected species, since there is the possibility that the remote triggered quick release for the end of the RZ may not be able to be activated and allow for the escape in the remote possibility that a protected species does become entangled in the S002; therefore, the residual impact significance for protected species would remain **2 – Low** as such an incident could be significant at the population level to that species with a regional extent.

During plastics extraction operations the S002 is towed by one vessel, at a slower speed, and has a narrowed wingspan (approximately 5 m) which significantly reduces the area swept by the system. Plastics extraction operations are anticipated to take a maximum of 12 hrs for each extraction and will occur approximately 5 times during the first 6-week campaign and less often during the subsequent 6-week campaigns. Although the quick release portion of the escape aids mitigation measure is not implemented during plastics extraction operations, all other mitigation measures are in effect. Extraction operations will be performed during daylight hours which will allow for the visual monitoring mitigation measures to be most effective. Based on the implementation of the mitigation measures; the reduced wingspan of S002 during extraction operations; planned daylight hours of plastics extraction operations; and additional operational actions that would be implemented (i.e., additional reduced vessel speed, shortening of catenary length, holding system wings in the current only); as necessary; it is expected that the likelihood would remain remote and the impact intensity would be reduced due to a smaller area for capture; impact consequence; however, is expected to slightly increase since there is no quick release in the event that a marine mammal became entangled in the shortened system. However, this increase would not be significant enough to change the overall impact significance of **1 – Negligible** during plastic extraction operations prior to implementation of mitigation measures.

5.2.4.3 S002 – Attraction/Ingestion of Plastics

Potential Impacts

Some marine mammals may be attracted to offshore structures, while others will avoid the floating S002. Marine mammals have been known to ingest trash and debris. Gall and Thompson (2015) reported that 30 species of marine mammals have ingestion records with marine debris. Debris items may be mistaken for food and ingested, or the debris item may have been ingested accidentally with other food. Marine mammals that are either attracted to the S002 or encounter it

[13] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

by chance may have a high probability of ingesting plastics due to the plastic-congregating feature of the S002. If a marine mammal mistakes the congregated plastic for a food source, a substantial amount of plastic could be ingested by a single individual. Debris ingestion can lead to loss of nutrition, internal injury, intestinal blockage, starvation, and death (NOAA, 2015). However, records suggest that entanglement is a far more likely cause of mortality to marine mammals than ingestion-related interactions (Laist et al., 1999).

By design, the S002 is expected to accumulate marine debris, which may include lines, nets, and other materials that have the potential to be ingested by marine mammals that could result in impact of moderate intensity; however, the marine debris is captured by the wings of the system and guided into the RZ, which is a closed net system which limits the potential access by marine mammals to the accumulated marine debris. The Ocean Cleanup estimates that up to 80 tons of plastic and debris may accumulate within the S002 RZ between extraction operations that will occur at approximately 1.2 to 2-week intervals. The long-term impacts of S002 on marine mammals should be **Beneficial** due to the removal of large amounts of plastics and other marine debris from the NPSG, Since the marine debris is guided from S002 wings into the RZ, the possibility of harm or death of marine mammals resulting from plastic ingestion is remote, the consequence severity is considered minor with a remote likelihood of impacts. Overall, the impact significance is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to marine mammal ingestion. These mitigation measures include the following:

- **Visual monitoring** – Monitoring during the project will identify marine mammals that may be near tow vessels with:
  - PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
  - Multiple above and underwater cameras will be installed above and inside the RZ.

- **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.

- **Acoustic deterrent** – Banana pingers attached to the system to deter approach of marine mammals.

Residual Impacts

Based on the mitigation measures that the Ocean Cleanup will implement and the short-term nature of the activities, the likelihood component of impact consequence would be reduced; however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.4.4 Vessel – Physical Presence/Strikes

Potential Impacts

Some marine mammals may be attracted to offshore structures, while others will avoid the vessels. There is a remote possibility of the vessels striking a marine mammal during transit to the NPSG and during routine operations. Variables that contribute to the likelihood of a strike include vessel speed, vessel size and type, barriers to vessel detection by an animal (e.g., acoustic masking, heavy traffic, biologically focused activity), and, in some cases, mitigation measures. Collisions with whales and particularly dolphins are considered highly unlikely; most dolphins are agile swimmers and are unlikely to collide with vessels (Laist et al., 2001; Jensen and Silber, 2003; Glass et al., 2009; Van der

Hoop et al., 2015). Most reports of collisions involve large whales, but collisions with smaller species have been reported as well (Laist et al., 2001; van Waerebeek et al., 2007; Douglas et al., 2008; Pace, 2011). Large whale species most frequently involved in vessel strikes include the fin whale (*Balaenoptera physalus*), North Atlantic right whale (NARW) (*Eubalaena glacialis*), humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), sperm whale (*Physeter macrocephalus*), sei whale (*Balaenoptera borealis*), grey whale (*Eschrichtius robustus*), and blue whale (*Balaenoptera musculus*) (Dolman et al., 2006). Laist et al. (2001) provided records of the vessel types associated with collisions with whales. From these records, most severe and lethal whale injuries involved large ships of lengths >80 m (262 ft). Vessel speed was found to be a significant factor as well, with 89% of the records involving vessels moving at 14 knots or greater (Laist et al., 2001).

Marine mammals at risk in the North Pacific Ocean for possible vessel strikes include slow-moving species and deep-diving species while on the surface (e.g., Bryde's whales, sperm whales, pygmy/dwarf sperm whales, beaked whales). Of the large whale species present in the project area, blue whale, fin whale, humpback whale, and gray whales are considered the most at-risk for vessel strikes because they migrate in nearshore areas where vessel traffic is heaviest (NOAA, nd).

When considering the level of commercial traffic off the western Canadian and United States coast, the proposed activities by The Ocean Cleanup do not contribute significantly to the overall vessel traffic in the region due to the short-term nature of the project. Based on these factors, the likelihood of a collision between a project-related vessel and a marine mammal is considered remote. If a collision did occur, it could result in the injury or death of the individual resulting in a moderate intensity impact. Potential collisions with marine mammals are not expected to occur with high enough frequency to have population level effects on any species resulting in a minor consequence. Consequently, the overall impact on marine mammals from vessel collisions is expected to be **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to marine mammal collision. These mitigation measures include the following:

- **Visual monitoring** – Monitoring during the project will identify marine mammals that may be near tow vessels with:
  - PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
  - Multiple above and underwater cameras will be installed above and inside the RZ.

- **Vessel operations**
  - Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots);
  - Towing vessels in the NPSG will travel as extremely slow speeds (0.5 to 2.5 knots); and
  - Debris collection vessels will maintain a watch for marine mammals when travelling to and from the NPSG.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement including the slow vessel speeds during routine operations (0.5- to 2.5 knots) and transit to and from the NPSG (<14 knots) as well as follow standard transit routes from the Vancouver area; and the short-term nature of the activities, the likelihood would be reduced; however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.4.5 *Noise and Lights*

Potential Impacts

The Ocean Cleanup proposed activities will generate vessel and equipment noise that could disturb marine mammals. The types of sounds produced by these sources are classified as non-pulsed, or continuous. Vessel noise is a combination of narrow-band (tonal) and broadband sound (Richardson et al., 1995). Tones typically dominate up to approximately 50 Hz, whereas broadband sounds may extend to 100 kHz. Analyses of radiated sound from ships have revealed that they are the dominant source of underwater noise at frequencies below 300 Hz in many areas (Okeanos, 2008).

Vessel and equipment noise from project vessels, including the towing, monitoring, and debris collection activities would produce sound levels typically <190 dB_{rms} re 1 µPa 1 m. The current acoustic thresholds for injurious exposure (PTS onset) and noninjurious (TTS onset) exposure to a continuous noise source, based on marine mammal hearing group, are presented below in **Table 5-5**.

Table 5-5. Underwater Acoustic Thresholds from Continuous Sound (Nonimpulsive) for Onset of Permanent (PTS), Temporary (TTS) Threshold Shifts, and Behavior Thresholds in Marine Mammal Hearing Groups.

Marine Mammal Hearing Group	PTS[1]		TTS[2]		Behavior[3]	
	Acoustic Metric	Threshold Value	Acoustic Metric	Threshold Value	Acoustic Metric	Threshold Value
Low-frequency Cetaceans (baleen whales)	SEL_{24h}	199 dB re 1 µPa^2 s	SEL_{24h}	179 dB re 1 µPa^2 s	SPL	120 dB re 1 µPa
Mid-frequency Cetaceans (dolphins, toothed whales, beaked whales, and bottlenose whales)	SEL_{24h}	198 dB re 1 µPa^2 s	SEL_{24h}	178 dB re 1 µPa^2 s	SPL	120 dB re 1 µPa
High-frequency Cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchids)	SEL_{24h}	173 dB re 1 µPa^2 s	SEL_{24h}	153 dB re 1 µPa^2 s	SPL	120 dB re 1 µPa
Phocid Pinnipeds (Underwater)	SEL_{24h}	201 dB re 1 µPa^2 s	SEL_{24h}	186 dB re 1 µPa^2 s	SPL	120 dB re 1 µPa
Otariid Pinnipeds (Underwater)	SEL_{24h}	219 dB re 1 µPa^2 s	SEL_{24h}	199 dB re 1 µPa^2 s	SPL	120 dB re 1 µPa

µPa = micropascal; dB = decibel; h = hour; PTS = permanent threshold shift; re = referenced to; s = second; SEL_{24h} = sound exposure level over 24-hours; SPL = root-mean-square sound pressure level; TTS = temporary threshold shift.
[1]PTS thresholds are for marine mammals from National Marine Fisheries Service (NMFS, 2018). Injury here is defined as the onset of potential mortal injury in sea turtles (Fisheries Hydroacoustic Working Group [FHWG], 2008).
[2]TTS thresholds derived from Southall et al. (2019).
[3]Behavioral thresholds derived from NMFS (2019).

The current acoustic threshold for behavioral effect exposure is 120 dB_{rms} re 1 µPa (NMFS, 2018). The behavioral effect threshold was based on avoidance responses observed in whales, specifically from research on migrating gray whales and bowhead whales (Malme et al., 1983, 1984, 1988; Richardson et al., 1986, 1990; Dahlheim and Ljungblad, 1990; Richardson and Malme, 1993). Mysticete whales, such as the Bryde's whale, are especially vulnerable to impacts from vessel noise because they produce and perceive low-frequency sounds (Southall, 2005). Broadband propulsion source levels for vessels are within the audible frequency range for most cetacean species (including Bryde's whales) and, near these sources, are anticipated to be in the range of 170 to 180 dB re 1 µPa m at the source. In the open ocean deepwater environment where spherical spreading conditions apply, an attenuation of 60 re 1 µPa m dB (e.g., reduction from a source level of 180 dB re 1 µPa m to the 120-dB continuous noise threshold) would occur within 1 km (0.6 mi) of the source. Where modified spherical spreading conditions may apply, the distance from source to the 120-dB threshold would be greater.

In addition to direct injurious or sub-injurious exposures, an additional effect of increased ambient noise on marine mammals is the potential for that noise to mask biologically significant sounds. Studies of vessel noise on Gulf of Mexico sperm whales indicated a significant decrease in the total number of acoustic clicks detected as a tanker ship approached an area (Azzara et al., 2013). Individuals of several small toothed whale and dolphin species have been observed to avoid boats when they are within 0.5 to 1.5 km (0.3 to 0.9 mi), with occasional reports of avoidance at greater distances (Richardson et al., 1995). Most beaked whales tend to avoid vessels (Würsig et al., 1998; Aguilar-Soto et al., 2006) and may dive for an extended period of time when approached by a vessel (Kasuya, 1986). Dolphins may tolerate boats of all sizes, often approaching and riding the bow and stern waves (Shane et al., 1986; Barkaszi et al., 2012). At other times, dolphin species that typically are attracted to boats will avoid them. Such avoidance is often linked to previous boat-based harassment of the animals (Richardson et al., 1995). Coastal bottlenose dolphins that are the object of whale watching activities have been observed to swim erratically (Acevedo, 1991), remain submerged for longer periods of time (Janik and Thompson, 1996; Nowacek et al., 2001), display less cohesiveness among group members (Cope et al., 1999), whistle more frequently (Scarpaci et al., 2000), and display restless behavior (Constantine et al., 2004) when boats are nearby.

The additional volume of vessel traffic associated with The Ocean Cleanup proposed activities would not constitute a significant increase to the existing vessel traffic offshore of the western Canadian and United States coasts, but the presence of the vessels in the NPSG could present a novel, persistent noise source. Additionally, the use of GTTSs, MRUs, and banana pingers will add novel anthropogenic noise to the local oceanic soundscape. Impacts to marine mammals from project-related vessel and equipment noise will be occasional but are expected to have a negligible impact consequence that would include temporary disruption of communication or echolocation from auditory masking; disturbance (behavioral disruptions) of individual or localized groups of marine mammals; and limited, localized, and short-term displacement of individuals of any species, including strategic stocks, from localized areas around the vessels. Because the operation will occur in the open ocean, animals are expected to avoid the sound source and the potential for resultant auditory injuries. Consequently, impacts to marine mammals from project-related noise is expected to be **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a two mitigation measures to help reduce potential impacts to marine mammal from noise. These mitigation measures include the following:

- **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable.
- **Visual cue/Acoustic deterrent** – Banana pingers will be used to potentially deter porpoises and high frequency hearing dolphins away from the system.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, two components of impact consequence, intensity and likelihood, would be reduced however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.4.6 Loss of Debris

Potential Impacts

Global entanglement records with trash and debris for marine mammals show that entanglement is most common in pinnipeds, less common in mysticetes, and rare among odontocetes (Laist et al., 1999). As discussed in **Section 5.2.4.3**, marine mammals have been known to ingest trash and debris.

MARPOL is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. MARPOL includes regulations aimed at preventing and minimizing pollution from ships (accidental and that from routine operations) and currently includes six technical Annexes. Special areas with strict controls on operational discharges are included in most Annexes. Annex V ("Prevention of Pollution by Garbage from Ships") deals with different types of trash and debris, specifying the distances from land and the manner in which they may be disposed of; the most important feature of Annex V is the complete ban imposed on the disposal into the sea of all forms of plastics. The revised Annex V prohibits the discharge of all trash and debris into the sea, except as provided otherwise. All other trash and debris must be returned to shore for proper disposal with municipal and solid waste.

In addition, the debris removal activities will occur onboard a vessel as the RZ will be hauled onboard a vessel and detached from S002. Therefore, the potential for lost debris that has been collected is remote and even if some of this debris was to be accidentally lost, it would return to its origin of the NPSG and would not constitute additional debris.

Taking into account the MARPOL regulations, the accidental loss of trash and debris from the transit, normal operations, or debris collection vessels activities is expected to be remote, and as such, the associated impact consequence is expected to be negligible. Consequently, debris entanglement and ingestion impact significance from lost debris on marine mammals is expected to be **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a mitigation measure to help reduce potential impacts to marine mammal from loss of debris. The implemented mitigation measure consists of the following:

- **Pollution prevention –** Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plans, potentially reducing the likelihood of occurrence.

Residual Impacts

Based on the mitigation measure that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.4.7 Accidental Fuel Spill

Potential Impacts

Diesel fuel most often is a light, refined petroleum product classified by the API as a Group 1 oil based on its specific gravity and density and is not persistent within the marine environment (Mediterranean Decision Support System for Marine Safety [MEDESS4MS], 2017). When spilled on water, diesel oil quickly spreads to a thin sheen; marine diesel, however, may form a thicker film of dull or dark colors. Because diesel oil is lighter than water (specific gravity is between 0.83 and 0.88, compared with 1.03 for seawater), it cannot sink and accumulate on the seafloor as pooled or free oil unless adsorption with sediment occurs. However, diesel oil dispersed by wave action may form droplets small enough to be kept in suspension and moved by currents (NOAA, 2017d). As diesel spreads on the sea surface, evaporation of the oil's lighter components occurs. Evaporation rates increase in conditions of high winds and sea state as well as high atmospheric and sea surface temperatures (American Petroleum Institute [API], 1999; MEDESS4MS, 2017; NOAA, 2017d). Small diesel spills usually evaporate and disperse naturally within a day.

Marine mammals could be affected by spilled diesel fuel. Effects of spilled oil on marine mammals are discussed by Geraci and St. Aubin (1980, 1982, 1985, 1990) as well as Lee and Anderson (2005) and within spill-specific study results (Frost and Lowry, 1994; Paine et al., 1996; Hoover-Miller et al., 2001; Peterson et al., 2003). Quantities of diesel fuel on the sea surface may directly affect marine mammals through various pathways: surface contact of the fuel with skin and mucous membranes of eyes and mouth; inhalation of concentrated petroleum vapors; or ingestion of the fuel (direct ingestion or by the ingestion of oiled prey).

Whales and dolphins apparently can detect slicks on the sea surface but do not always avoid them; therefore, they may be vulnerable to inhalation of hydrocarbon vapors, particularly those components that are readily evaporated. Ingestion of the light hydrocarbon fractions found in diesel fuel can be toxic to marine mammals. Ingested diesel fuel can remain within the gastrointestinal tract and be absorbed into the bloodstream and, thus, irritate and/or destroy epithelial cells in the stomach and intestines. Certain constituents of diesel fuel (i.e., aromatic hydrocarbons, PAHs) include some well-known carcinogens. These substances, however, do not show significant biomagnification in food chains. While some hydrocarbon components may be metabolized, recent data indicate that acute exposure to hydrocarbons (i.e., crude oil from the *Deepwater Horizon* spill) marine mammals exhibited symptoms of hypoadrenocorticism, consistent with adrenal toxicity as previously reported for laboratory mammals exposed to oil (Schwacke et al., 2013). Released fuel may also foul the baleen fibers of mysticete whales, thereby impairing food-gathering efficiency or result in the ingestion of fuel or fuel-contaminated prey.

The likelihood of a fuel spill during project activities is considered remote, and the potential for contact with and impacts to marine mammals would depend heavily on the size and location of the spill as well as weather and sea conditions at the time of the spill. For this scenario, fuel spilled on the sea surface is assumed to rapidly spread to a thin layer and break into narrow bands or windrows that are aligned parallel to the wind direction. Lighter volatile components of the fuel would evaporate almost completely in a few days.

Because of the thickness of the slick and rapid weathering, it is not likely that many animals would come into contact with the fuel on the surface. Potential impacts are assumed to be negligible to minor mucous membrane irritation and behavioral alteration (temporary displacement) from the affected area resulting in a moderate impact intensity and minor impact consequence. The impact significance of spilled fuel to marine mammals is expected to be **1 – Negligible**, depending on the species coming into contact with the spilled fuel and their exposure time to the spilled fuel.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to marine mammal from an accidental fuel spill. These mitigation measures include the following:

- **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained.

- **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.
- **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings.
- **No re-fueling at sea** – No re-fueling will occur at sea.
- **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.4.8 *Marine Mammal Impact Summary*

Impact Rating

Impact	Intensity	Extent	Duration	Consequence	Likelihood	Impact Significance
Removal of plastics and debris from the environment	Removal plastics and other marine debris (i.e., ghost nets) from the NPSG will result in the long-term reduction in the potential impact of marine mammal entanglement; the potential for marine mammals to ingest plastics and for marine mammals to be impacted by the release of degradation by-products (e.g., release of toxic chemicals).					
Entanglement in the S002 or accumulated debris resulting in injury or death during both plastics collection operations and plastics extraction operations	High	Immediate Vicinity Regional (Protected Species)	Short Term	Moderate	Remote	2 – Low
Attraction to S002; ingestion of congregated plastics resulting in injury or death	Moderate	Immediate Vicinity	Short Term	Minor	Remote	1 – Negligible
Exposure to vessel strike resulting in injury or death	Moderate	Immediate Vicinity	Short Term	Minor	Remote	1 – Negligible
Behavioral modification changes (e.g., evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels)	Low	Local	Short Term	Negligible	Occasional	1 – Negligible
Entanglement with, or ingestion of, debris accidentally lost	Low	Immediate Vicinity	Short Term	Negligible	Remote	1 – Negligible
Diesel fuel exposure, including inhalation of vapors, ingestion, fouling of baleen	Moderate	Immediate Vicinity	Short Term	Minor	Remote	1 – Negligible

Mitigation Measures

<table>
<tr><th>Impact</th><th>Mitigation Measures</th><th>Component of Impact Consequence Affected by Mitigation</th><th>Residual Impact Significance</th></tr>
<tr><td rowspan="2">Entanglement in The Ocean Cleanup System (S002) or accumulated debris resulting in injury or death for both plastics collection operations and plastics extraction operations</td><td rowspan="2">Routine debris extraction - Routinely remove accumulated debris (e.g., plastics, fishing nets) approximately every 1.2 to 2 weeks from the S002 RZ.
Visual monitoring – Monitoring during the project will identify marine mammals that may be near tow vessels with:
PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
Multiple above and underwater cameras will be installed above and inside the RZ.
Visual cues – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.
Acoustic deterrent – Banana pingers attached to the system will potentially deter porpoises and high frequency hearing dolphins away from the system.
Escape aids – System equipped with a remote triggered quick release for the end of the RZ to free entangled marine mammals and the RZ will be allowed to rest for 30 to 60 minutes prior to retrieval to give marine mammals time to escape.[14]
Breathing port – Floaters will be attached to the netting in the retention area to raise the netting approximately 50 cm to guarantee access to air for marine mammals.
Rescue of animals – Rescue attempts of entangled marine mammals in distress may be attempted according to the Environmental Management Plan.</td><td>Reduces Intensity and Likelihood</td><td>1 – Negligible</td></tr>
<tr><td>Reduces Likelihood (Protected Species)</td><td>2 – Low
For Protected Species</td></tr>
</table>

[14] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance

Attraction to the S002; ingestion of congregated plastics resulting in injury or death	• **Visual monitoring** – Monitoring during the project will identify marine mammals that may be near tow vessels with:
	  o PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
	  o Multiple above and underwater cameras will be installed above and inside the RZ.
	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.
	• **Acoustic deterrent** – Banana pingers attached to the system will potentially deter porpoises and high frequency hearing dolphins away from the system.
		Reduces Likelihood	1 – Negligible

Exposure to vessel strike resulting in injury or death	• **Visual monitoring** – Monitoring during the project will identify marine mammals that may be near tow vessels with:
	  o PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
	  o Multiple above and underwater cameras will be installed above and inside the RZ.
	• **Vessel operations** –
	  o Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots);
	  o Towing vessels in the NPSG will travel as extremely slow speeds (0.5–2.5 knots); and
	  o Vessels will maintain a watch for marine mammals when travelling to and from the NPSG.
		Reduces Intensity and Likelihood	1 – Negligible

Behavioral modification changes (e.g., evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (support vessels)	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. • **Visual cue/Acoustic deterren**t – Banana pingers will be used to potentially deter porpoises and high frequency hearing dolphins away from the system.	Reduces Intensity and Likelihood	1 – Negligible
Entanglement with, or ingestion of, debris accidentally lost	• **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plans, potentially reducing the likelihood of occurrence.	Reduces Likelihood	1 – Negligible

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Diesel fuel exposure, including inhalation of vapors, ingestion, fouling of baleen	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels. • **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization and during the time at sea, if necessary. Fuel hoses will be equipped with dry-break couplings. Any re-fueling required will only be undertaken in safe working weather conditions and good lighting. • **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.	Reduces Likelihood	1 – Negligible

5.2.5 Potential Impacts on Sea Turtles

5.2.5.1 Impact Producing Factor(s)

- S002 – Entanglement/Entrapment
- S002 – Attraction/Ingestion of Plastics
- Vessel Strikes
- Noise and Lights
- Loss of Debris
- Accidental Fuel Spill

5.2.5.2 S002 – Entanglement/Entrapment

Potential Impacts

The physiology of turtles makes them susceptible to entanglement, as their surface area is large, and they are not as streamlined as marine mammals. Sea turtle feeding behavior makes turtles susceptible to entanglement, as many species tend to forage near surface waters where floating debris often concentrates. Hamelin et al. (2017) summarized recent incidental captures of leatherback turtles offshore Canada in the Atlantic Ocean and reported that entanglements were most common in pot gear that utilized polypropylene line near the surface. Numerous other studies report that sea turtles are common bycatch in gillnet and longline fisheries (Byrd et al., 2016).

S002 consists of nets, lines, floats, and chains and could potentially entangle sea turtles; however, the likelihood of entanglement in the S002 itself would be rare because the system moves slowly; and it is expected that sea turtles would be able to visually identify the S002 and actively avoid contact during deployment and operations in the NPSG.

By design, S002 is expected to accumulate marine debris during plastics collection operations, which may include lines, nets, and other materials which may attract sea turtles, especially hatchlings, to the structure and cover that the S002 provides and become entangled. If a sea turtle did become entangled in lines, nets or chains connected to S002 or in marine debris, nets, or lines accumulated within S002, the individual could be harmed or drown if it were unable to untangle itself and result in an impact of high intensity with a regional extent. It should be noted that while possible, the death of a sea turtle during plastics collection operations it is considered remote and that overall, the long-term impacts of S002 on sea turtles should be **Beneficial** due to the removal of large amounts of plastics and other marine debris from the NPSG. Impacts on sea turtles from entanglement/entrapment are considered rare and of moderate consequence severity (injury or death of individual turtles). Overall impact significance prior to mitigation is rated **2 – Low** during plastics collection operations.

During plastics extraction operations, where S002 is towed by one vessel, at a slower speed, and has a narrowed wingspan, the likelihood of a sea turtle becoming entangled is also considered remote and is reduced from the likelihood during plastics collection operations due to the narrowed wingspan and slower towing speed. The other aspects of impacts in the event that a sea turtle did become entangled, intensity, extent, duration, and consequence would remain the same as during plastics collection operations; and therefore, the overall impact significance rating of **2 – Low** would remain for plastics extraction operations prior to implementation of mitigation measures.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to sea turtles from entanglement/entrapment. These mitigation measures include the following:

- **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near tow vessels with:
  - PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
  - Multiple above and underwater cameras will be installed above and inside the RZ.

- **Visual cues** – Use of white flashing LED lights to enhance detectability of the System.

- **Escape aids** – System equipped with a remote triggered quick release for the cod end to free entangled sea turtles[15] and the net will be allowed to rest 30 to 60 minutes prior to retrieval to give sea turtles time to escape.

- **Breathing port –** Floaters will be attached to the netting in the retention area to raise the netting approximately 20 cm to guarantee access to air for sea turtles.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement during plastics collection operations and the short-term nature of the activities, two components of impact consequence, intensity and likelihood, would be reduced. However, there is the possibility that the remote triggered quick release for the end of the RZ may not be able to be activated and allow for the escape in the remote possibility that a protected sea turtle does become entangled in the S002 which could cause population level impacts with a regional extent; therefore, the residual impact significance for protected species would remain **2 – Low**.

During plastics extraction operations the S002 is towed by one vessel, at a slower speed, and has a narrowed wingspan (approximately 5 m) which significantly reduces the area swept by the system. Plastics extraction operations are anticipated to take a maximum of 12 hrs for each extraction and will occur approximately 5 times during the first 6-week campaign and less often during the subsequent 6-week campaigns. Although the escape aids quick release mitigation measure is not implemented during plastics extraction operations, the system is planned to be towed with the cod end opened and all other mitigation measures are in effect. Extraction operations will be performed during daylight hours which will allow for the visual monitoring mitigation measures to be most effective. Based on the implementation of the mitigation measures; the reduced wingspan of S002 during extraction operations; daylight hours of plastics extraction operations; and additional operational actions that would be implemented (i.e., additional reduced vessel speed, shortening of catenary length, holding system wings in the current only); it is expected that the likelihood would remain remote and the impact intensity would be reduced due to a smaller area for potential capture; impact consequence; however, if the cod end is not left open during extraction operations, the impact consequence is expected to increase since there is no quick release in the event that a sea turtle became entangled in the shortened system (i.e., during plastic extraction). However, this

[15] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

increase would not be significant enough to change the overall impact significance of **1 – Negligible** during plastic extraction operations prior to implementation of mitigation measures.

5.2.5.3 S002 – Attraction/Ingestion of Plastics

Potential Impacts

Certain sea turtles, especially loggerheads, may be attracted to offshore structures (Lohoefener et al., 1990; Gitschlag et al., 1997) and thus may be more susceptible to impacts from other risk factors at the S002 deployment location, including sounds produced during routine operations and vessel strikes.

Due to the expected relatively high concentrations of marine plastics in the vicinity of the S002, any turtles attracted to the structure of the S002 may be at increased risk of consuming plastic particles. However, the marine debris captured by the wings of the system is guided into the RZ, which is a closed net system which shortens the duration of the potential access by sea turtles to the accumulated marine debris. Ingestion of debris can kill or injure sea turtles and is considered a significant stressor (Laist, 1987; Lutcavage et al., 1997; Fukuoka et al., 2016). In a review, Gall and Thompson (2015) reported that all species of sea turtles have published reports of entanglement or ingestion of marine debris. Olive ridley turtles are considered to have the highest risk for consuming plastics because they spend a majority of their life in the pelagic environment (Bolten, 2003) and because their foraging strategy on zooplankton and fish often occurs in current convergence zones that correspond to areas where plastics tend to collect (Schuyler et al., 2016). Fukuoka et al. (2016) reported that green turtles had higher encounter-ingest ratios than did loggerheads when studied using turtle mounted cameras, but Pham et al. (2017) reported than 83% of juvenile loggerheads investigated in the North Atlantic gyre has ingested plastic. Leatherback turtles can also be susceptible to floating plastics, particularly plastic bags, because they resemble their preferred food of jellyfish (Mrosovsky et al., 2009). A recent study (Clukey et al., 2017) investigated stomach contents of 55 sea turtles that were caught as bycatch in the Pacific Ocean and found that all olive ridley (n= 37), 90% of green (n= 10), 80% of loggerhead (n= 5), and 0% of leatherbacks (n= 5) had plastics in their stomachs or intestines. It should be noted however, that not all turtles were caught from the same area and exposure to plastics for all specimens may not have been equal.

Any impacts on turtles due to attraction to the S002 would likely be short term and of negligible consequence; but impacts from plastic ingestion could cause chronic impacts to affected individuals. However, due to the relatively small size of the S002 and the low density of sea turtles in the remote open ocean area of the S002 deployment, it is not expected that impacts to turtles from plastics ingestion will be biologically significant to sea turtle populations. However, juvenile turtles are mostly pelagic, spending most of their time in the open ocean. Juvenile loggerhead turtles are known to utilize the project area (Kobayashi et al., 2008; Abecassis et al., 2013; Briscoe et al., 2016a,b) and may be vulnerable to impacts from plastic ingestion. Loggerhead turtles, which are known to migrate through the area of the S002 deployment are known to eat plastic bags, possibly due to a resemblance to their preferred food of jellyfish. Impacts to regional populations are possible, but considered unlikely. Impacts on sea turtles from attraction to the S002 and the associated ingestion of plastics are considered occasional, moderate intensity and of minor consequence severity. Overall impact significance prior to mitigation is rated **2 – Low**.

It is also important to note, however, that the presence of plastics in the ocean, in particular abandoned fishing gear and lines, present a significant danger to turtle species. The S002, by facilitating removal of these materials from the environment, presents a potential for long-term **Beneficial** impact to sea turtle species.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to sea turtles from attraction/ingestion of plastics. These mitigation measures include the following:

- **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near tow vessels with:
  - PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and
  - Multiple above and underwater cameras will be installed above and inside the RZ.

- **Visual cues** – Use of white flashing LED lights to enhance detectability of the System.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood component of impact consequence would be reduced resulting in a residual impact significance of **1 – Negligible**.

5.2.5.4 Vessel – Physical Presence/Strikes

Potential Impacts

There is a rare possibility of the vessels striking a sea turtle during transit or operations. Vessel strikes have been identified as a source of injury and mortality and are among the threats affecting the endangered population status of several sea turtle species (NRC, 1990; Foley et al., 2019). Vessel strikes happen when a sea turtle or vessel fails to detect one another in time to react and avoid the collision. Variables that contribute to the likelihood of a strike include vessel speed, vessel size and type, barriers to vessel detection by an animal (e.g., acoustic masking, heavy traffic, biologically focused activity), and, in some cases, mitigation measures. Most reports of vessel strikes involve large whales, but collisions with sea turtles have been reported (Foley et al., 2019).

When considering the level of commercial traffic off the western Canadian and United States coast, the proposed activities by The Ocean Cleanup do not contribute significantly to the overall vessel traffic in the region. Studies indicate that sea turtles are at the sea surface only about 10% of the time and readily sound (dive) to avoid approaching vessels (Byles, 1989; Lohoefener et al., 1990; Keinath and Musick, 1993; Keinath et al., 1996). Based on these factors, the likelihood of a collision between a project-related vessel and a sea turtle is considered rare. In the event a vessel strikes a sea turtle, it could result in injury or death of the individual resulting in an impact intensity of high. Due to the slow speed of the vessels during both transit (<14 knots) and operations (between 0.5 to 2.5 knots), potential collisions with sea turtles are not expected to occur with high enough frequency to have population level effects on any species resulting in a moderate consequence; therefore, the likelihood of striking any sea turtle is considered rare. Overall impact significance is rated **2 – Low**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to sea turtles from vessel strikes. These mitigation measures include the following:

- **Vessel operations –** Vessel speeds will be kept to a minimum for specific operations as follows:
  - Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots);

- Towing vessels in the NPSG will travel as extremely slow speeds (0.5 to 2.5 knots); and
- Project's vessels will maintain a watch for sea turtles and when travelling to and from the NPSG.

- **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near vessels with:
  - Crew member PSOs during transit; and
  - PSOs during operations and use of one forward- looking Thermal/RGB camera system.

Residual Impacts

Potential collisions with sea turtles are not expected to occur with high enough frequency to have population level effects on any species. In addition, based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, two components of impact consequence, intensity and likelihood, would be reduced resulting in a residual impact significance of **1 – Negligible**.

5.2.5.5 Noise and Lights

Potential Impacts

There is scarce information regarding hearing and acoustic thresholds for marine turtles. However, what is known is that sea turtles have low-frequency hearing capabilities, typically hearing frequencies from 30 Hz to 2 kHz, with a range of maximum sensitivity between 100 and 800 Hz (Ridgway et al., 1969; Lenhardt, 1994; Bartol and Ketten, 2006). Hearing below 80 Hz is less sensitive but may be important biologically (Lenhardt, 1994). Summaries of sea turtle hearing capabilities has been prepared by Bartol (2014, 2017).

By species, hearing characteristics of sea turtles include:

- Loggerhead sea turtle: greatest sensitivities around 250 Hz or below for juveniles, with the range of effective hearing from at least 250 to 1,000 Hz (Lavender et al., 2012a,b,c; 2014);
- Green sea turtle: greatest sensitivities are 300 to 500 Hz (Ridgway et al., 1969); juveniles and subadults detect sounds from 100 to 500 Hz underwater, with maximum sensitivity at 200 and 400 Hz (Bartol and Ketten, 2006) or between 50 and 400 Hz (Dow et al., 2008); peak response at 300 Hz (Yudhana et al., 2010a);
- Hawksbill sea turtle: greatest sensitivities at 50 to 500 Hz (Yudhana et al., 2010b);
- Olive ridley sea turtle: juveniles of a congener (Kemp's ridley) found to detect underwater sounds from 100 to 500 Hz, with a maximum sensitivity between 100 and 200 Hz (Bartol and Ketten 2006); and
- Leatherback sea turtle: a lack of audiometric information is noted in this species; their anatomy suggests hearing capabilities are similar to other sea turtle species, with functional hearing assumed to be 10 Hz to 2 kHz.

The current acoustic thresholds for injurious exposure (PTS onset) and behavior from exposure to a continuous noise source, based on sea turtle hearing, is presented below in **Table 5-6**.

Table 5-6. Underwater Acoustic Thresholds from Continuous Sound (Nonimpulsive) for Onset of Permanent Threshold Shift and Behavior Threshold in Sea Turtles.

Faunal Group	PTS[1]		TTS[2]		Behavior[3]	
	Acoustic Metric	Threshold Value	Acoustic Metric	Threshold Value	Acoustic Metric	Threshold Value
Sea turtles	SPL	180 dB re 1 µPa	-	-	SPL	175 dB re 1 µPa

- = not available; µPa = micropascal; dB = decibel; PTS = permanent threshold shift; re = referenced to; SPL = root-mean-square sound pressure level; TTS = temporary threshold shift.
[1]PTS threshold with injury here is defined as the onset of potential mortal injury in sea turtles (Fisheries Hydroacoustic Working Group [FHWG], 2008).
[2]TTS threshold is not available for sea turtles.
[3]Behavioral threshold derived from sea turtles = Blackstock et al. (2018).

Sounds have the potential to impact a sea turtle in several ways: masking of biologically significant sounds, alteration of behavior, trauma to hearing (temporary or permanent), and trauma to non-hearing tissue (barotraumas) (McCarthy, 2004). Anthropogenic noise, even below levels that may cause injury, has the potential to mask relevant sounds in the environment. Masking sounds can interfere with the acquisition of prey, affect the ability to locate a mate, diminish the ability to avoid predators, and, particularly in the case of sea turtles, adversely affect the ability to properly identify an appropriate nesting site (Nunny et al., 2008); however, there are no data demonstrating masking effects for sea turtles.

Based on transmission loss calculations (Urick, 1983), open water propagation of noise produced by typical sources with dynamic position (DP) thrusters in use, are not expected to produce SPL_{rms} greater than 160 dB re 1 µPa beyond 105 ft (32 m) from the source. Certain sea turtles, especially loggerheads, may be attracted to offshore structures (Lohoefener et al., 1990, Gitschlag et al., 1997, Colman et al., 2020) and thus, may be more susceptible to impacts from sounds produced from DP use during operations.

The most likely effects of vessel and equipment noise on sea turtles would include behavioral changes. Vessel and equipment noise is transitory and generally does not propagate at great distances from the vessel, and the source levels are too low to cause death or injuries such as auditory threshold shifts. Based on existing studies on the role of hearing in sea turtle ecology, it is unclear whether masking would realistically have any effect on sea turtles (Mrosovsky, 1972; Samuel et al., 2005; Nunny et al., 2008). Behavioral responses to vessels have been observed but are difficult to attribute exclusively to noise rather than to visual or other cues. It is conservative to assume that noise associated with survey vessels may occasionally elicit behavioral changes in individual sea turtles near vessels. These behavioral changes may include evasive maneuvers such as diving or changes in swimming direction and/or speed which would result in a low intensity impact. This evasive behavior is not expected to adversely affect these individuals or the population, and impacts are expected to be significant. Impact consequence from all noise sources to sea turtles is expected to be negligible.

Artificial lighting can disrupt the nocturnal orientation of sea turtle hatchlings (Tuxbury and Salmon, 2005, Berry et al., 2013, Simões et al., 2017). However, hatchlings may rely less on light cues when they are offshore than when they are emerging on the beach (Salmon and Wyneken, 1990). NMFS (2007) concluded that the effects of lighting from offshore structures on sea turtles are insignificant. Therefore, no significant impacts are expected from lighting on the vessels. Therefore, given the likely nature of impact from noise and light, the overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to sea turtles from noise and light. These mitigation measures include the following:

- **Elimination of unnecessary acoustic energy –** The levels of anthropogenic noise will be kept as low as reasonably practicable. Sound generated by banana pingers is localized and is well above hearing ranges of sea turtles.

- **Visual cue –** Use of white flashing LED lights to enhance detectability of the System.

- **Minimize night-time deck lighting** – The level of lights onboard the vessels will be kept as low as reasonably practicable to maintain a safe work environment at night.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, two components of impact consequence, intensity and likelihood, would be reduced however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.5.6 Loss of Debris

Potential Impacts

The disposal of trash and debris in the ocean is prohibited under MARPOL, and all project vessels will ensure adherence to MARPOL. However, the occasional and unintentional loss of debris may occur (e.g., floating trash, buckets containing paints or other chemicals). Materials accidentally lost overboard during the project may also float on the ocean surface or within the water column (e.g., plastic bags, packaging materials). Floating debris, especially plastics and monofilament line, could entangle marine fauna, or cause injury through ingestion. There is a remote possibility that S002 will fail or break apart at sea during the deployment and become marine debris itself.

Marine debris is among the threats affecting the endangered population status of several sea turtle species (NRC, 1990). Ingestion of or entanglement with accidentally discarded debris can kill or injure sea turtles (Lutcavage et al., 1997). Leatherback turtles are especially attracted to floating debris, particularly plastic bags, because it resembles their preferred food, jellyfish. Ingestion of plastic and Styrofoam can result in drowning, lacerations, digestive disorders or blockage, and reduced mobility.

Through adherence to MARPOL and the short-term nature of the Ocean Cleanup activities, impacts on sea turtles from the loss of debris are considered remote and would be of negligible consequence severity. Overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a mitigation measure to help reduce potential impacts to sea turtles from loss of debris. The mitigation measure consists of the following:

- **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plan.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced; however, the resulting residual impact significance would remain **1 – Negligible.**

5.2.5.7 Accidental Fuel Spill

Potential Impacts

Diesel fuel in the marine environment may affect sea turtles through various pathways: direct contact, inhalation of diesel fuel, its volatile components, and ingestion of diesel fuel (directly or indirectly through the consumption of fouled prey species). Several aspects of sea turtle biology and behavior place them at risk, including lack of avoidance behavior, indiscriminate feeding in convergence zones, and inhalation of large volumes of air before dives (Milton et al., 2003). Diesel fuel can adhere to turtle skin or shells. Turtles surfacing within or near a diesel fuel release would be expected to inhale petroleum vapors. Ingested diesel fuel, particularly the lighter fractions, can be toxic to sea turtles. Hatchling and juvenile turtles feed opportunistically at or near the surface in oceanic waters and are especially sensitive to released hydrocarbons (including diesel fuel) resulting in an impact of moderate intensity with minor consequence.

The likelihood of a fuel spill during project activities is considered remote, and the potential for contact with and impacts to sea turtles would depend heavily on the size and location of the spill as well as weather and sea conditions at the time of the spill. For this scenario, fuel spilled on the sea surface is assumed to rapidly spread to a thin layer and break into narrow bands or windrows that are aligned parallel to the wind direction. Lighter volatile components of the fuel would evaporate almost completely in a few days. Therefore, the impact consequence to sea turtles from an accidental diesel fuel spill is expected to be minor due to the low volume of fuel spill, expected density of these resources, relatively short period of diesel fuel or presence on the sea surface, and high degree of dissolution, spreading, and evaporation. The likelihood of impacts on sea turtles from a fuel spill are considered remote and the overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to sea turtles from an accidental fuel spill. These mitigation measures include the following:

- **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained.

- **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.

- **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings.
- **No re-fueling at sea** – No re-fueling will occur at sea.
- **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.5.8 *Sea Turtle Impact Summary*

Impact Rating

Impact	Intensity	Extent	Duration	Consequence	Likelihood	Impact Significance
Removal of plastics and debris from the environment	Removal plastics and other marine debris (i.e., ghost nets) from the NPSG will result in the long-term reduction in the potential impact of marine mammal entanglement; the potential for sea turtles to ingest plastics and for sea turtles to be impacted by the release of degradation by-products (e.g., release of toxic chemicals).					
Entanglement or entrapment with deployed S002 or accumulated debris	High	Regionally	Short Term	Moderate	Rare	2 – Low
Attraction to S002; ingestion of congregated plastics resulting in injury or death	Moderate	Immediate Vicinity	Short Term	Minor	Occasional	2 – Low
Injury or mortality resulting from a vessel collision with a sea turtle	High	Immediate Vicinity	Short Term	Moderate	Rare	2 – Low
Behavioral modification changes (e.g., diving, evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels); attraction to light	Low	Local	Short Term	Negligible	Occasional	1 – Negligible
Entanglement with, or ingestion of, debris accidentally lost	Low	Immediate Vicinity	Short Term	Negligible	Remote	1 – Negligible
Diesel fuel exposure, including inhalation of vapors, ingestion	Moderate	Immediate Vicinity	Short Term	Minor	Remote	1 – Negligible

Mitigation Measures

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Entanglement or entrapment with deployed S002 or accumulated debris	• **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near tow vessels with: ○ PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and ○ Multiple above and underwater cameras will be installed above and inside the RZ. • **Visual cues** – Use of white flashing LED lights to enhance detectability of the System. • **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled sea turtles[16] and the net will be allowed to rest prior to retrieval to give sea turtles time to escape. • **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 50 cm to guarantee access to air for sea turtles. • **Routine debris extraction** – Routinely remove accumulated debris (e.g., plastics, fishing nets) approximately every 1.2 to 2 weeks from S002 RZ. • **Rescue of animals** – Rescue attempts of entangled sea turtles in distress may be attempted according to the Environmental Management Plan.	Reduces Likelihood	2 – Low*
Attraction to S002; ingestion of congregated plastics resulting in injury or death	• **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near tow vessels with: ○ PSOs and use of one forward- and one backwards-looking Thermal/RGB camera system; and ○ Multiple above and underwater cameras will be installed above and inside the RZ. • **Visual cues** – Use of white flashing LED lights to enhance detectability of the System.	Reduces Likelihood	1 – Negligible

[16] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Injury or mortality resulting from a vessel collision with a sea turtle	• **Vessel operations** – Vessel speeds will be kept to a minimum for specific operations as follows: o Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots); o Towing vessels in the NPSG will travel as extremely slow speeds (0.5–2.5 knots); and o Vessels will maintain a watch for sea turtles and when travelling to and from the NPSG. • **Visual monitoring** – Monitoring during the project will identify sea turtles that may be near vessels with: o Crew member PSOs during transit; and o PSOs during operations and use of one forward- looking Thermal/RGB camera system.	Reduces Intensity and Likelihood	1 – Negligible
Behavioral modification changes (e.g., diving, evasive swimming, disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (vessels), attraction to light	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. Sound generated by banana pingers is localized and is well above the hearing ranges of sea turtles. • **Visual cue** – Use of white flashing LED lights to enhance detectability of the System. • **Minimize night-time deck lighting** – The level of lights onboard the vessels will be kept as low as reasonably practicable to maintain a safe work environment at night.	Reduces Likelihood	1 – Negligible
Entanglement with, or ingestion of, debris accidentally lost	• **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plans, potentially reducing the likelihood of occurrence.	Reduces Intensity and Likelihood	1 – Negligible*
Diesel fuel exposure, including inhalation of vapors, ingestion	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.	Reduces Likelihood	1 – Negligible

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Diesel fuel exposure, including inhalation of vapors, ingestion (cont'd)	• **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization and during the time at sea, if necessary. Fuel hoses will be equipped with dry-break couplings. Any re-fueling required will only be undertaken in safe working weather conditions and good lighting. • **No re-fueling at sea** – No re-fueling will occur at sea. • **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.		

*= Negligible impact significance was generated assuming operations for S002 would occur prior to the end of nesting season and prior to hatchlings enter the oceanic environment.

5.2.6 Potential Impacts on Coastal and Oceanic Birds

5.2.6.1 Impact Producing Factor(s)

- S002 – Entanglement/Entrapment
- S002 – Attraction/Ingestion of Plastics
- Vessel – Physical Presence/Strikes
- Noise and Lights
- Loss of Debris
- Accidental Fuel Spill

For coastal and oceanic birds, the physical presence of the S002 and vessels and the attraction of birds to these (often due to lighting) are related and will be discussed together to avoid repetition.

5.2.6.2 S002 and Vessel – Entanglement/Entrapment/Attraction/Physical Presence/Strikes

Potential Impacts

Many seabird species, such as frigatebirds, boobies, tropicbirds, albatrosses, gulls, jaegers, procellarid petrels, and some storm-petrels are attracted to offshore structures and vessels for a variety of reasons such as roosting sites, rest areas during migration, shelter during inclement weather, lighting, flaring, food availability, and other visual cues (Wall and Heinemann, 1979; Tasker et al., 1986; Montevecchi et al., 1999; Wiese et al., 2001; Black, 2005; Montevecchi, 2006; Ronconi et al., 2015). Additionally, some birds engage in ship-following as a foraging strategy, especially with commercial or recreational fishing vessels (Garthe and Huppop, 1994).

As such, birds in the project area may experience both beneficial impacts as well as negative impacts from the presence of the S002 and vessels. Some birds may use the S002 as a stopover site for resting and feeding, while some birds may be attracted to the S002 lights and become engaged in nocturnal circulations (Russell, 2005; Montevecchi, 2006). Others that are attracted to offshore structures may suffer mortality from collision or starvation (Russell, 2005; Montevecchi, 2006; Ellis et al., 2013; Ronconi et al., 2015). The presence of the S002 may also displace birds from otherwise suitable foraging habitat (Ronconi et al., 2015). However, the use of the S002 or vessels may increase the survivability of individuals using the structures to rest or as shelter during bad weather conditions in the open waters (Russell, 2005) or the S002 may provide additional foraging opportunities for seabirds (Tasker et al., 1986; Ronconi et al., 2015).

Additionally, birds using the S002 for roosting may be indirectly impacted by an increased possibility of entanglement or ingestion of plastic found in the NPSG. Birds such as albatrosses, petrels and shearwaters, storm petrels and diving petrels, have been observed to have ingested more plastics compared to other birds (Blastic, 2017). In addition, these birds have small gizzards and many of them are unable to regurgitate indigestible items, which makes them even more vulnerable to the effects of plastic ingestion (Li et al., 2016). Plastic ingestion can affect foraging behavior, diet, breeding, molting and distribution of species. Both the entanglement rate and amount of plastic ingested by seabirds varies with their foraging practices, feeding technique, and diet (Li et al., 2016).

Pelagic seabirds feed according to three different methods: diving, plunge diving and/or surface feeding (**Figure 5-3**). These three different feeding techniques will alter the type of encounter birds have with both the marine plastic and the S002. Birds that use plunge diving or diving (e.g., albatross, boobies, gannets) have an increased chance of becoming entangled in debris, while surface feeders feeding on plankton have been shown to contain more plastic as during surface feeding it is often easier to mistake plastic as food (Azzarello and Van Vleet, 1987; Li et al., 2016).

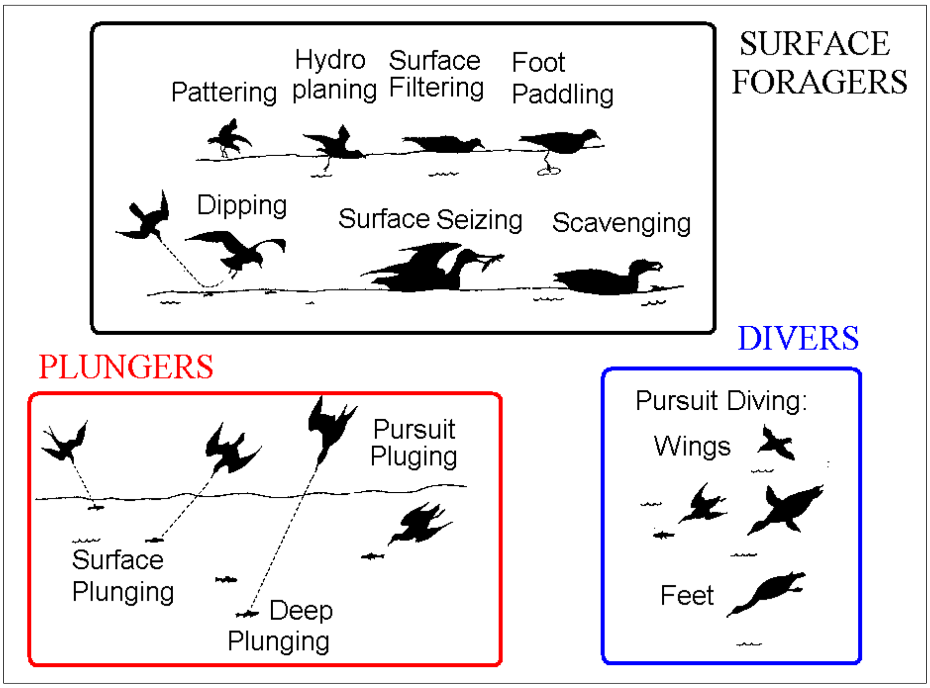

Figure 5-3. Seabirds feeding modes (From: Nevins et al., 2005).

The potential for bird strikes on a vessel is not expected to be significant to individual birds or their populations (Klem, 1989, 1990; Dunn, 1993; Erickson et al., 2005; Merkel, 2010). Given the rare likelihood of collision, the impacts are not expected to result in mortality or serious injury to individual birds, resulting in limited impacts to these types of seabirds from vessel attraction. Shorebirds are not known to be attracted to vessels. However, these birds may fly in a lower altitude pattern for inclement weather conditions during migrations which may increase the potential for a vessel strike.

Most impacts from operations of the S002 and vessels would be short term and in the immediate vicinity of the NPSG or along vessel routes to and from port and would likely affect relatively few individuals or habitats since the S002 and support activities will occur far from the coastline and any sensitive bird habitats. Although rare, some mortality could occur for birds colliding with the tow vessels resulting in a high intensity impact; however, impacts from such collisions are anticipated to affect relatively few birds and result in no population-level effects on birds. Plastics collection activities are not expected to significantly affect oceanic birds due to the low bird density at the remote deployment location in the NPSG. The long-term impacts of S002 could be **Beneficial** for seabirds because the removal of plastics and other marine debris (i.e., ghost nets) from the NPSG will result in the long-term reduction in the potential impact of seabird entanglement; the potential for seabirds to ingest plastics; and for seabirds to be impacted by the release of degradation by-products (e.g., release of toxic chemicals).

Since birds may use S002 for resting or roosting, they could be indirectly impacted by an increased possibility of entanglement or ingestion of plastic found in the NPSG. Although rare, because of the possibility of harm or death of seabirds due to entanglement with S002 or collected debris, would result in a high intensity impact with a consequence severity of moderate.

Any impacts on seabirds due to attraction to S002 would likely be short term and minor; but impacts from plastic ingestion could cause chronic impacts to affected individuals. However, due to the relatively small size of S002 and the low density of seabirds in the remote open ocean area of S002 deployment, it is expected that impacts to seabirds from plastics ingestion could occur occasionally and would result in impacts of moderate intensity and minor consequence.

Therefore, impact consequence from entanglement/entrapment and attraction/ingestion of accumulated plastics associated with the S002 and the physical presence/strikes associated with vessels to coastal and oceanic birds is expected to range from minor to moderate for plastics collection operations. The likelihood of these impacts ranges from rare to occasional and the overall impact significance prior to mitigation is rated **2 – Low** for plastics collection operations.

During plastics extraction operations, where S002 is towed by one vessel and has a narrowed wingspan, the likelihood of an oceanic bird becoming entangled is considered remote and is reduced from collection operations. The other aspects of impacts in the event that a seabird did become entangled, intensity, extent, duration, and consequence would remain the same as during collection operation; and therefore, the overall impact significance rating of **2 – Low** would remain for plastics extraction operations prior to implementation of mitigation measures.

During plastics extraction operations, where S002 is towed by one vessel, at a slower speed, and has a narrowed wingspan, the likelihood of a seabird becoming entangled is also considered remote and is reduced from the likelihood during plastics collection operations due to the narrowed wingspan and slower towing speed. The other aspects of impacts in the event that a seabird did become entangled, intensity, extent, duration, and consequence would remain the same as during plastics collection operations; and therefore, the overall impact significance rating of **2 – Low** would remain for plastics extraction operations prior to implementation of mitigation measures.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to coastal and oceanic birds from entanglement, entrapment, attraction, physical presence, and strikes. These mitigation measures include the following:

- **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.
- **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled seabirds[17] and the net will be allowed to rest prior to retrieval to give seabirds time to escape.
- **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 20 cm to guarantee access to air for seabirds.
- **Vessel operations –** Vessel speeds will be kept to a minimum for specific operations as follows:
  - Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots); and
  - Towing vessels in the NPSG will travel as extremely slow speeds (0.5 to 2.5 knots).

[17] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement during plastics collection operations and the short-term nature of the activities, two components of impact consequence (i.e., intensity and likelihood) would be reduced resulting in a residual impact significance of **1 – Negligible** for plastics collection operations.

Although the escape aids quick release mitigation measure is not implemented during plastics extraction operations; however, the system is planned to be towed with the cod end opened and all other mitigation measures are in effect and the vessel towing speed will be reduced to holding S002 wings in the current. Based on the implementation of the mitigation measures, the reduced wingspan of S002 during extraction operations, the resulting residual impact significance would remain **1 – Negligible** for plastics extraction operations.

5.2.6.3 Noise and Lights

Potential Impacts

Disturbance related impacts to seabirds and other migratory birds from vessel noise and lighting will vary depending on the type, intensity, frequency, duration, and distance to the disturbance source (Conomy et al., 1998; Blumstein, 2003). Seabirds may be affected by vessel noise in a variety of manners including disturbance resulting in behavioral changes (Béchet et al., 2004; Agness et al., 2008; Schoen et al., 2013); selection of alternative habitats or prey that may be suboptimal; creating barriers to movement or decreasing available habitat (Bayne et al., 2008); decreases in foraging time and efficiency (Schwemmer et al., 2011); reduced time spent resting or preening (Tarr et al., 2010); and increases in energy expenditures due to flight behavior (versus resting, preening, or foraging) (Agness et al., 2008, 2013). The primary potential impacts to seabirds from vessel noise are from underwater sound generated by propeller(s), dynamic positioning, and machinery and would include behavioral modification changes (e.g., disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels); and attraction to vessels lights.

Overall disturbance-related and behavioral change impacts do not typically result in direct mortality (Larkin, 1996; Carney and Sydeman, 1999). Birds disturbed by the presence of project vessels may flee a habitat and may or may not return. Displacement would be short term and transient in most cases and would not be expected to result in any lasting effects. Most of the underwater noise associated with vessels is low-frequency (<200 Hz) (Richardson et al., 1995) and on the lower end of bird hearing range (Dooling and Popper, 2007). Potential impacts to diving seabirds are not expected to result in auditory injuries but will be limited to disturbance (behavioral) reactions (e.g., interruption of activities, short- or long-term displacement) resulting in low intensity impacts. Due to the short-term duration of noise that will be generated by the S002 operation including vessels, impact consequence to birds from noise are expected to be negligible. Given the occasional nature of impacts from noise, overall impact significance prior to mitigation is rated **1 – Negligible**.

Impacts from lighting would result in potential attraction to the vessels with impact intensity, consequence, and likelihood associated with vessel strike, entanglement, entrapment discussion in **Section 5.2.6.2**. Given the likely nature of this impacts from lighting, overall impact significance prior to mitigation is rated **2 – Low**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to coastal and oceanic birds from noise and lights. These mitigation measures include the following:

- **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable. Sound generated by banana pingers is localized.

- **Limit lighting** – Lights will be limited at night to the extent practicable. Navigational lights on the system will flash intermittently to reduce shining light in the water at night.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the intensity and likelihood of impact consequence would be reduced resulting in a residual impact significance of **1 – Negligible** for both noise and lighting.

5.2.6.4 Loss of Debris

Potential Impacts

The disposal of trash and debris in the ocean is prohibited under MARPOL, and all project vessels will ensure adherence to MARPOL. However, the occasional and unintentional loss of debris may occur. Materials accidentally lost overboard during the project may also float on the ocean surface or within the water column (e.g., plastic bags, packaging materials). Floating debris, especially plastics poses a potential hazard to seabirds, through entanglement and ingestion (Laist, 1987; Derraik, 2002, Li et al., 2016). The ingestion of plastic by coastal and oceanic birds can cause obstruction and ulceration of the gastrointestinal tract, which can result in mortality (Li et al., 2016). In addition, accumulation of plastic in seabirds has been shown to be correlated with the body burden of polychlorinated biphenyls, which can cause lowered steroid hormone levels and result in delayed ovulation and other reproductive problems (Pierce et al., 2004). Additional impacts include blockage of gastric enzyme secretion, diminished feeding stimulus, reproductive failure, and adults that manage to regurgitate plastic particles could pass them onto the chicks during feeding (Derraik, 2002).

Seabirds are also vulnerable to entanglement encounters, which can lead to mortality (Li et al., 2016). The effects of entanglement can be summarized as drowning, suffocation, laceration, reduced fitness, a reduced ability to prey or an increased probability of being caught (Laist, 1987; Derraik, 2002; Li et al., 2016). The entanglement incidence for a species depends on its behavior (Derraik, 2002). The plunge diving fishing method of some seabirds (e.g., gannets, boobies) has been shown to lead to a high rate of entanglement encounters, partly because the birds mistake floating plastic debris for fish or other food items (Li et al., 2016). This mode of feeding may be the primary reason for the entanglement encounters of seabirds. The accidental loss of trash and debris associated with the S002 is expected to be remote with adherence to MARPOL, as such, associated impact consequence is expected to be negligible. Overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a mitigation measure to help reduce potential impacts to coastal and oceanic birds from loss of debris. The mitigation measure consists of the following:

- **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plan.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced; however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.6.5 Accidental Fuel Spill

Potential Impacts

Direct contact of coastal and oceanic birds with diesel fuel, particularly in close proximity to the spill location, may result in the fouling or matting of feathers with subsequent limitation or loss of flight capability or insulating or water-repellent capabilities; irritation or inflammation of skin or sensitive tissues, such as eyes and other mucous membranes; or toxic effects from ingested diesel fuel or the inhalation of diesel fuel and its volatile components (Kennicutt et al., 1991; Mazet et al., 2002). However, impact consequences to coastal and oceanic birds from a diesel fuel spill are expected to be minor due to the low volume of fuel spill, expected density of these resources, relatively short period of diesel fuel presence on the sea surface, and high degree of dissolution, spreading, and evaporation. The likelihood of impacts on coastal and oceanic birds from a fuel spill are considered rare and the overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to coastal and oceanic birds from an accidental fuel spill. These mitigation measures include the following:

- **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained.
- **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.
- **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings.
- **No re-fueling at sea** – No re-fueling will occur at sea.
- **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced; however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.6.6 Coastal and oceanic birds Impact Summary

Impact Rating

Impact	Intensity	Extent	Duration	Consequence	Likelihood	Significance
Removal of plastics and debris from the environment	Removal plastics and other marine debris (i.e., ghost nets) from the NPSG will result in the long-term reduction in the potential impact of marine mammal entanglement; the potential for marine mammals to ingest plastics and for marine mammals to be impacted by the release of degradation by-products (e.g., release of toxic chemicals).					
Entanglement or entrapment with deployed S002	High	Immediate Vicinity	Short Term	Moderate	Rare	2 – Low
Attraction to S002; ingestion of congregated plastics resulting in injury or death	Moderate	Immediate Vicinity	Short Term	Minor	Occasional	2 – Low
Injury or mortality resulting from a vessel collision with a bird due to attraction from lights	High	Immediate Vicinity	Short Term	Moderate	Rare	2 – Low
Behavioral modification changes (e.g., disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels)	Low	Immediate Vicinity	Short Term	Negligible	Occasional	1 – Negligible
Entanglement with, or ingestion of, debris accidentally lost	Low	Immediate Vicinity	Short Term	Negligible	Remote	1 – Negligible
Diesel fuel exposure, including inhalation of vapors, ingestion	Moderate	Immediate Vicinity	Short Term	Minor	Rare	1 – Negligible

Mitigation Measures

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Entanglement or entrapment with deployed S002	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System. • **Escape aids** – System equipped with a remote triggered quick release for the end of the RZ to free entangled seabirds[18] and the net will be allowed to rest for 30 to 60 minutes prior to retrieval to give seabirds time to escape. • **Breathing port** – Floaters will be attached to the netting in the retention area to raise the netting approximately 50 cm to guarantee access to air for seabirds.	Reduces Intensity and Likelihood	1 – Negligible
Attraction to S002; ingestion of congregated plastics resulting in injury or death	• **Visual cues** – Use of light colored netting to increase visual detectability for wings and RZ and use of white flashing LED lights to enhance detectability of the System.	Reduces Likelihood and Intensity	1 – Negligible
Injury or mortality resulting from a vessel collision with a bird due to attraction from lights	• **Limit lighting** – Lights will be limited at night to the extent practicable. Navigational lights on the system will flash intermittently to reduce shining light in the water at night.	Reduces Likelihood and Intensity	1 – Negligible
Behavioral modification changes (e.g., disruption of activities, departure from the area) from noise exposure; avoidance of noise sources (tow vessels)	• **Elimination of unnecessary acoustic energy** – The levels of anthropogenic noise will be kept as low as reasonably practicable.	Reduces Likelihood and Intensity	1 – Negligible
Entanglement with, or ingestion of, debris accidentally lost	• **Pollution prevention** – Verify compliance with International Convention for the Prevention of Pollution from Ships (MARPOL) restrictions and implementation of vessel Waste Management Plans, potentially reducing the likelihood of occurrence.	Reduces Likelihood	1 – Negligible

[18] Depending on the tow distance of the cod end of S002 from the vessel, this mitigation measure may not be able to be activated 100% of the time. This mitigation measure is not in effect during towing of the shortened System during plastics extraction operations; however, the system is planned to be towed with the cod end opened.

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Diesel fuel exposure, including inhalation of vapors, ingestion	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels. • **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization and during the time at sea, if necessary. Fuel hoses will be equipped with dry-break couplings. • **No re-fueling at sea** – No re-fueling will occur at sea. • **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.	Reduces Likelihood	1 – Negligible

5.2.7 Potential Impacts on Protected Areas

5.2.7.1 Impact Producing Factor(s)

- Vessel – Physical Presence/Strikes
- Accidental Fuel Spill

5.2.7.2 Vessel Physical Presence/Strikes

Potential Impact

Based on the proposed route to the test site, The Ocean Cleanup vessels will transit past several coastal protected areas that can be avoided completely with strategic routing. However once offshore, the likelihood of project vessels traversing a portion of the Endeavour Hydrothermal Vents MPA is high. No significant impacts are expected on this and other MPAs, but some minor disturbance of wildlife could occur due to vessel noise.

It is likely that wildlife in the MPAs have become accustomed to disturbances associated with vessel traffic due to the ubiquity of vessel traffic in the region originating from the Vancouver area and Victoria Harbour. Vessel strikes are not expected to occur to resources within the protected areas, however, if a strike were to occur, impacts could be significant (**Sections 5.2.4**, **5.2.5**, and **5.2.6**). Impact consequence from the physical presence/strikes associated with project vessels to protected areas is expected to be negligible. Based on the short term and transient nature of the transit through or adjacent to the MPAs, the likelihood of any impacts is expected to be rare and the overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement two mitigation measures to help reduce potential impacts to protected areas from physical presence, and strikes. These mitigation measures include the following:

- **Strategic routing** – to avoid protected areas when practicable; and

- **Vessel operations** – Vessel speeds will be kept to a minimum for transit as vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots) and obey all separation scheme restrictions.

Residual Impacts

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced; however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.7.3 Accidental Fuel Spill

Potential Impacts

An accidental diesel spill in an MPA during vessel transit would dissipate rapidly and would only likely affect organisms in the immediate location of the release. Diesel fuel used for operation of support vessels is light and would float on the water surface. Diesel fuel spilled at the ocean surface will rapidly disperse and weather, with volatile components evaporating.

Impacts to protected species, including marine mammals, sea turtles, and coastal and oceanic birds, will be similar to those previously noted for these resources (i.e., direct contact; inhalation of volatile components; ingestion directly or indirectly through the consumption of fouled prey species; fouling or matting of feathers with subsequent limitation or loss of flight capability or insulating or water-repellent capabilities; irritation or inflammation of skin or sensitive tissues).

Impact consequence to protected areas and habitats of concern from a diesel fuel spill is expected to be minor due to the low volume of a potential fuel spill, the relatively short period of diesel fuel presence on the sea surface, and high degree of dissolution, spreading, and evaporation. The likelihood of impacts on protected areas from a fuel spill are considered rare and the overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to wildlife within MPAs from an accidental fuel spill. These mitigation measures include the following:

- **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained.
- **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.
- **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization. Fuel hoses will be equipped with dry-break couplings.
- **No re-fueling at sea** – No re-fueling will occur at sea.
- **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain of command to The Ocean Cleanup, and other regulatory bodies.

Residual Impact

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, the likelihood of impact consequence would be reduced; however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.7.4 *Protected Area Impact Summary*

Impact Rating

Impact	Intensity	Extent	Duration	Consequence	Likelihood	Significance
Disturbance of wildlife in marine protected areas from vessel transit	Low	Immediate Vicinity	Short Term	Negligible	Rare	1 – Negligible
Exposure to diesel fuel, fouling of habitat	Moderate	Immediate Vicinity	Short Term	Minor	Remote	1 – Negligible

Mitigation Measures

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Disturbance of wildlife in marine protected areas from vessel transit	• **Strategic routing** – Vessel will avoid protected areas when practicable; and • **Vessel operations** – Vessel speeds will be kept to a minimum for transit as vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots) and obey all separation scheme restrictions.	Likelihood	1 – Negligible
Exposure to diesel fuel, fouling of habitat	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under the International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels.	Likelihood	1 – Negligible

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Exposure to diesel fuel, fouling of habitat (cont'd)	• **Shipboard Oil Pollution Emergency Plan (SOPEP)** – The Ocean Cleanup will ensure that a SOPEP is in place on all vessels, and that an Oil Record Book as required under MARPOL 73/78 will be maintained. • **Spill equipment on board** – Sorbent materials will be used to clean up any minor spill on board the survey vessels. • **Fuel transfer protocols** – Strict fuel transfer procedures will be implemented to prevent an accidental release during the loading of fuel at the port of mobilization and during the time at sea, if necessary. Fuel hoses will be equipped with dry-break couplings. • **No re-fueling at sea** – No re-fueling will occur at sea. • **Reporting procedures** – In the event of an accidental release of oil or other products, the incident will be immediately reported through the contractor chain-of-command to The Ocean Cleanup, and other regulatory bodies.		1 – Negligible

5.2.8 Potential Impacts on Commercial and Military Vessels

5.2.8.1 Impact Producing Factor(s)

- Vessel – Physical Presence/Strikes

5.2.8.2 Transit/Vessel Physical Presence

Potential Impacts

The Ocean Cleanup vessels will transit through the Strait of Juan de Fuca and the Salish Sea when traveling to and from Victoria Harbour. As described in **Section 4.4.1**, The Ocean Cleanup vessels will monitor NOTSHIP notifications prior to and during transit from the Port. Once offshore, it is not expected that the vessels will have interactions with commercial or recreational vessels; however, numerous vessels of these types will be located along the route. Additionally, military vessels may be present in the vicinity of Canadian Forces Base Esquimalt as The Ocean Cleanup vessels are transiting past.

It is not expected that the vessels will pass through any Military Warning Areas and no impacts on military training activities are expected. However, The Ocean Cleanup will comply with any Canadian military mandated area restrictions.

The impact consequence from vessel operations is expected to be negligible on commercial and military vessels. Given the short-term but likely nature of this impact, overall impact significance prior to mitigation is rated **1 – Negligible**.

Mitigation Measures

The Ocean Cleanup will implement a number of mitigation measures to help reduce potential impacts to commercial and military vessels from an accidental fuel spill. These mitigation measures include the following:

- **Vessel operations –** Vessel speeds will be kept to a minimum for specific operations as follows:
  - Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots); and
  - Towing vessels in the NPSG will travel as extremely slow speeds (0.5 to 2.5 knots).

- **Monitor notifications** – Vessels will monitor NOTSHIP notifications prior to and during transit from the Port.

Residual Impact

Based on the mitigation measures that The Ocean Cleanup will implement and the short-term nature of the activities, however, the resulting residual impact significance would remain **1 – Negligible**.

5.2.8.3 Commercial and Military Vessels Impact Summary

Impact Rating

Impact	Intensity	Extent	Duration	Consequence	Likelihood	Significance
Temporary increase of vessel traffic	Low	Immediate Vicinity	Short Term	Negligible	Likely	1 – Negligible

Mitigation Measures

Impact	Mitigation Measures	Component of Impact Consequence Affected by Mitigation	Residual Impact Significance
Temporary increase in vessel traffic	• **Vessel operations** – Vessel speeds will be kept to a minimum for specific operations as follows: o Transit vessels traveling between the shore and the NPSG will travel at slow speeds (<14 knots); and o Towing vessels in the NPSG will travel as extremely slow speeds (0.5–2.5 knots). • **Monitor notifications** – Vessels will monitor NOTSHIP notifications prior to and during transit from the Port.	None	1 – Negligible

6.0 Conclusions

A preliminary screening was completed (**Section 4.1**) to identify the biological and social resources at risk from the transit and deployment of the S002 in the NPSG. Resources that were determined to not be affected by S002 or where impact consequences were deemed, *a priori*, to be negligible were air quality, sediment quality, water quality, benthic communities, human resources, land use and economics, recreational resources and tourism, and physical oceanography. An impact assessment on the remaining resources (fish/fishery resources, plankton and neuston, marine mammals, sea turtles, coastal and oceanic birds, protected areas, commercial and military vessels) was conducted from a risk-based perspective to determine the overall significance of each potential impact based on its intensity, extent, duration, consequence and likelihood. Biodiversity was included in the screening process and determined that there is not enough information at this time to fully address biodiversity impacts from the S002. After the up to four, 6 week-long campaigns, data collected during the campaigns may be used, if feasible, in conjunction with existing Ecopath models, as well as any additional data from applicable scientific research studies, to develop a model specific for The Ocean Cleanup project. Application of these data within the framework of an Ecopath model may provide another tool to better evaluate any biodiversity impacts from The Ocean Cleanup activities. This information will be included in a Revised Final EIA.

Impacts provided are based upon the short duration campaign (up to four, 6 week-long campaigns) of the proposed S002. Deployment of S002 will test the efficacy of the new system design as well as applied mitigation measures. Additionally, the impact analysis was performed on a resource-by-resource basis and did not consider impacts at the ecosystem level. As such, the analysis does not address potential impacts on the trophic cascade and food web and community structures, nor does it fully address the net environmental benefit of plastic removal from the environment; these components are complex and will be addressed along with incorporating the data collected from the up to four, 6 week-long campaigns in a Revised Final EIA after the campaign.

An impact assessment of the removal of neuston (including ichthyoplankton) is very complex considering the variability within each of these groups. However, the distribution and abundance of these species within the NPSG is largely unknown, further limiting the confidence level afforded any impact determination. Additionally, it is also unknown what sort of catch rate S002 will have on the neuston community as well as other bycatch. As described, data collected as well as observations recorded during the up to four, 6 week-long campaigns are designed to collect data not only regarding S002 efficacy, but also to obtain additional data regarding the operations and bycatch collected by the system. This information will be included in a Revised Final EIA after campaign.

The initial analysis of routine operations (i.e., prior to application of mitigation measures) produced impact determinations that were predominately in the Negligible or Low categories, with several identified as Medium to High for plankton and neuston and Medium for fish and fisheries. Impacts from an accidental fuel spill were identified based on the accidental release of diesel fuel. Given the relatively small potential spill volume and weathering factors, the impacts to various resources from a fuel spill release were rated Negligible.

The Ocean Cleanup will prepare and implement an Environmental Management Plan (EMP) to identify and describe mitigation measures that will be employed to reduce or eliminate the potential environmental impacts identified in this EIA. Overall, when proper mitigation measures, maritime regulations, and industry best practices are applied, the significance of potential impacts of the proposed activities will generally be Negligible or Low, with the exception of entrapment by plankton and neuston is a Medium residual impact. Additionally, it is expected that the long-term positive impacts as a result of removing large amounts of floating plastic from the NPSG will likely provide a beneficial impact to all biological resources in the region.

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Appendix

Supporting Neuston Technical Data

Two neuston experts were contracted to provide guidance, identify key data sources, and to conduct a critical review of baseline, impacts, and mitigation measures text in support of EIA development in regards to neuston. Experts were contracted for their experience with neuston from the NPSG and their worldwide perspective on open ocean neuston communities. Neuston experts included: 1) Dr. Jenni Brandon, Applied Ocean Sciences, La Jolla, California; and 2) Dr. Delphine Thibault, Aix-Marseille Université, Mediterranean Institute of Oceanography, Marseille, France. Data and text provided by the neuston experts are cited in the EIA as Brandon (2021, personal communication) and Thibault (2021, personal communication). The data in the current appendix has undergone minimal editing (for consistency in presentation), and contains responses from each neuston expert to a series of questions pertaining to neuston distribution, generation times and life cycle information, and forcing mechanisms relevant to neuston presence.

A.1 QUESTIONS AND RESPONSES

A.1.1 Question 1: Is it possible to further define the spatial and temporal distribution patterns for neuston in the Eastern Pacific Garbage Patch (EPGP)?

Brandon: This is hard to do because many of these animals are truly drifters, and so their spatial distribution is really determined by the wind and weather/storm events. An interesting point is that *Velella velella* come in two orientations, a right-handed and a left-handed orientation, based on which way their sail orients, and they are thought to be equally mixed together in the center of the Pacific. By the time you get to the coasts of Asia and the coasts of North America on the edges of the Gyre, you almost always only find ones of one or the other orientation, as the wind has determined their distribution.

One of the larger animals of the neuston are the neon flying squid. They actually do have spatial and temporal migration patterns throughout the North Pacific, moving throughout the region for spawning and feeding, as well as performing diel vertical migration. For other species, like many fish, they are only in the neuston as larvae, and then they enter the epipelagic or mesopelagic zones as later life stages.

Thibault: With only one published set of data available (Moore et al., 2001), we cannot currently properly assess the neuston community of the EPGP. There is an obvious lack of data regarding the structure/functioning of the neuston in most area of the world’s ocean as shown by the low number of published articles. Collection of data on the species composition, seasonal, diel variations should be a priority, potential role of this community being certainly way underestimated. Temporal distribution of the neuston community will largely depend on the taxa composition of the community, their different diel and onto genic migrations, their different life cycles, and lifespan. Spatial pattern will follow mainly the mesoscale circulation, temperature, salinity and wind patterns within the area.

The only way to further define the spatial and temporal variation in the neuston community structure and distribution is by conducting survey within the considered area (i.e., EPGP, the area of subtropical high pressure, or the entire PGP). Combining efforts with scientists measuring microplastics could be a way forward but the actual procedure is for microplastics studies to digest the whole “organic matter” present in the sample (Cole et al., 2014).

A.1.2 Question 2: Are density estimates available for neuston in the EPGP (even a broad, high level range of density estimates is of interest)?

Brandon: The only density estimate available for the EPGP is Moore et al. (2001), that has the plankton:plastic density ratio as 5:1. An additional reference was found for the Atlantic gyre.

I also found another paper that attempted to estimate it acoustically, although it is not purely neuston and it is a first attempt (Lehodey et al., 2015).

Thibault: A single study by Moore et al. (2001) dealt with neuston abundance and biomass in the EPGP. This study is based on 11 stations along two transects of measuring 174 and 85 nautical miles. Authors indicated that the collected plankton were identified down to class, but actually no details of the taxonomic composition was given. Zooneuston mean abundance was 1,837,342 organisms km^{-2}, ranging from 54,003 to 5,076,403 organism km^{-2}. No information on the spatial variation along those two transects were given. Authors only highlighted the strong day/night component in the neuston community with zooneuston being at least three times more abundant at night. Moore et al. (2002) and Lattin et al. (2004) mentioned only ratios in term of biomass between neuston and plastics in an area east of the EPGP, very close to the coast.

A.1.3 Question 3: What are the generation times (or regeneration times) for key neuston species?

Brandon: Generation times are very dependent on the species. Some *Thalia* salp species complete the entire lifecycle in two days (Heron, 1972), and during blooms, they can be born already budding tails of the asexual clonal phase (Alldredge and Madin, 1982). Copepods are dependent on species and temperature but it is on the order of a week to 10 days. *Velella* are thought to take 125 days/4 months to reach maximum length (Bieri, 1977). For gooseneck barnacles it is on the scale of months.

Thibault: In order to understand truly the rate of population growth in a species it is actually important to know its generation (Cole, 1954). Different generation times (i.e., duration from egg to mature adults) will have a profound impact on several ecological processes and interactions (e.g., competition, predation) within a community. Differences in generation time among species can be attributed to size and weight, but also to life cycle complexity (e.g., number of stages). The neuston community is composed of species displaying different life strategies (i.e., holoplanktonic, meroplanktonic, and metagenic [metagenetic] species). Ontogenic and diel migrations are also important behaviors to account for when studying the neuston. *Note: The following group-specific summaries of generation time and life cycles for various neuston groups (**Sections A.1.3.1** through **A.1.3.5**) were provided by Dr. Thibault. Its presentation is intended to provide further details regarding life cycle stages, and is not intended to be North Pacific Subtropical Gyre-specific.*

A.1.3.1 Crustacea

A.1.3.1.1 Copepods

Fertilized eggs (from male and female gametes either directly released into the ocean or kept in a brooding/egg sac) hatch as nauplii and after six naupliar stages (molting between each stage), there are five copepodite stages (i.e., C1 through C5). The adult stage, stage copepodite C6 is then reached (**Figure A-1**). The development from egg to adult may take from less than a week to as long as several years; the life span of an adult female or male copepod ranges from six months to one year. Isochronally is usually reported for most stages; C5 duration is particularly variable and strategy dependent. Generation time is also affected by temperature and salinity (Baumgartner and Tarrant, 2017).

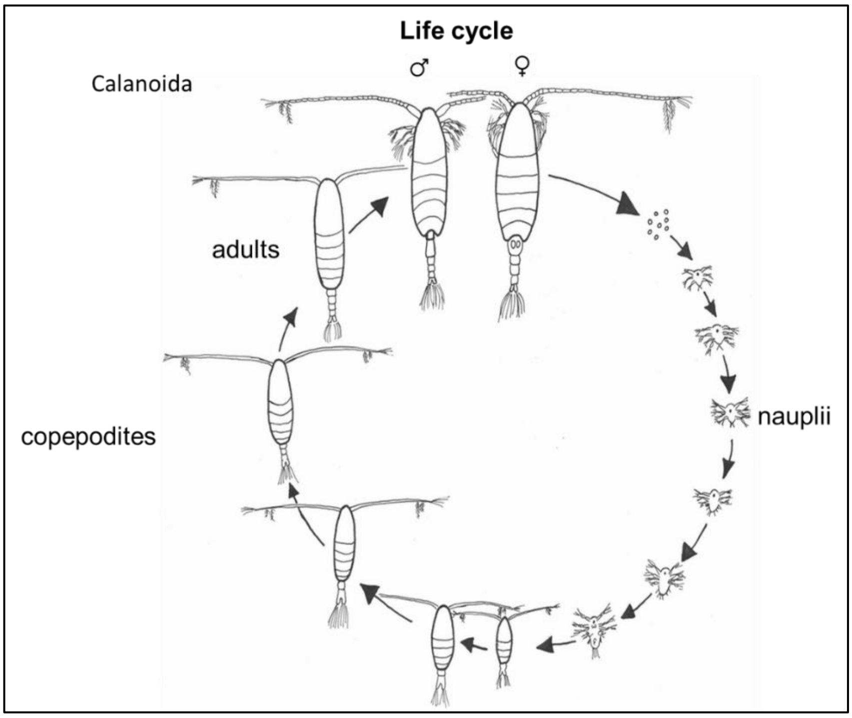

Figure A-1. Life cycle for calanoid copepods (From: NOAA, 2021).

Representative species and their respective generation times:

- *Temora longicornis*: 19 days (Klein Breteler et al., 1994);
- *Acartia clausi*: 17 days (Klein Breteler et al., 1994); and
- *Paraeuchaeta elongata*: 1 year (Ikeda and Hirakawa, 1996; Ozaki and Ikeda, 1997).

A.1.3.1.2 Euphausia

Generation time for euphausiids is approximately one year (Cuzin-Roudy et al., 2004).
Figure A-2 depicts the life stages for euphasiids.

A.1.3.1.3 Amphipoda

Most species complete their life cycle (egg to adult) in one year or less (Smith and Whitman, 1992).

A.1.3.2 Meroplanktonic Larvae (Crustacea, Echinodermata, Mollusca)

For these organisms, the duration of the planktonic larval phase is crucial in the dispersal of the larvae (Sponaugle et al., 2002). Information on marine invertebrate larval development times is rare.

Crustacea: lobsters, rock lobsters (economically important species). The planktonic larval phase includes three larval stages and one postlarval stage; exhibits a complex life cycle that has a direct effect on the transport potential of larvae and the connectivity of benthic populations through larval exchange (**Figure A-3**).

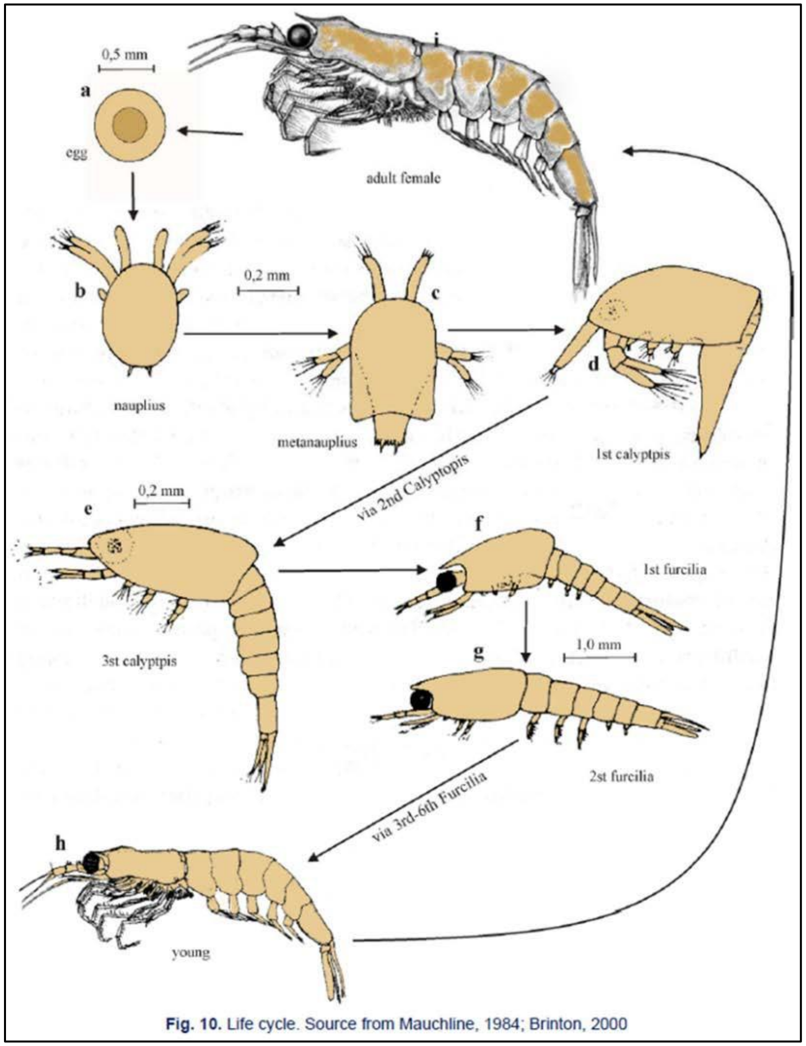

Figure A-2. Life cycle for euphasiids (From: Mauchline, 1984 and Brinton et al., 2000).

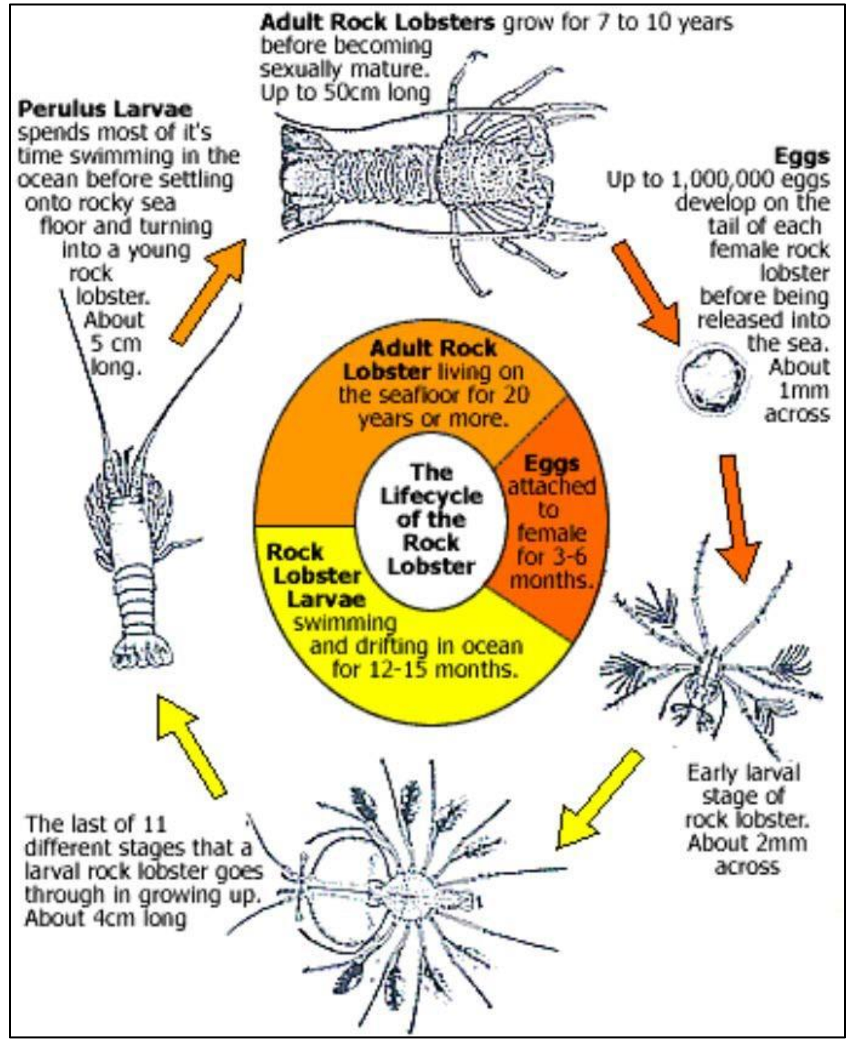

Figure A-3. Life cycle of rock lobster (From: New Zealand Rock Lobster Industry Council, 2021).

European spiny lobster (*Palinurus elephas*) is currently classified as **Vulnerable** under the International Union for Conservation of Nature (IUCN) Red List (IUCN, 2021; Goni, 2014). Planktonic larval duration ranges from 5 to 12 months depending on the region and seawater temperature (Groeneveld et al., 2013). This species has the potential to cover thousands of km before finally settling out of the water column and metamorphosing into juveniles.

Pronghorn spiny lobster (*Panulirus penicillatus*) has a long-lived teleplanic larval phase of at least 7 to 8 months (Matsuda et al., 2019).

Echinodermata (sea urchins, holothurians, sea stars, ophiuroids; **Figure A-4**). Sea urchin larval stages can last up to several months.

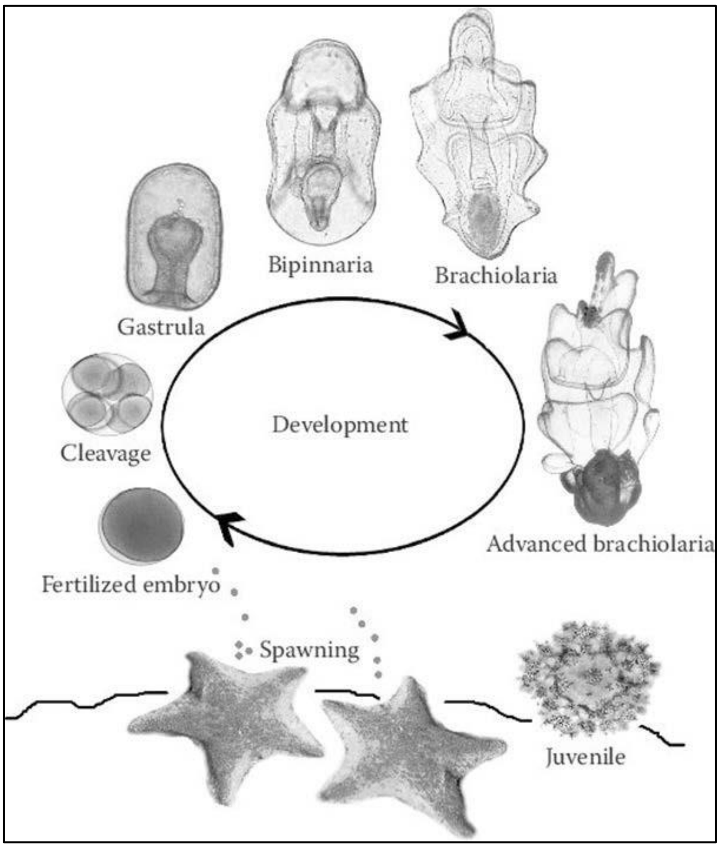

Figure A-4. Life cycle for echinoderms (From: Byrne, 2011).

Mollusca: Teleplanic (long-lived) larvae of meroplanktonic taxa are transported by currents across ocean basins (Laursen, 1981). Veliger larvae usually last for approximately two weeks before settling on the bottom of the ocean, but some species have been shown to live up to 4.5 years (e.g., *Fusitriton oregonensis*; Strathmann and Strathmann, 2007).

Pteropoda, holoplanktonic Mollusca, are permanent features in the neuston. They display year-round reproduction and an individual life span of approximately six months. Reared in the lab, the veliger stage was observed approximately seven days after egg fertilization, and metamorphosis into the juvenile stage occurred after approximately one month. Reproductive adults are usually observed after three months (Thabet et al., 2015).

A.1.3.3 Hydrozoans

A.1.3.3.1 Siphonophores

The generation time for siphonophores is about 2 weeks at 24°C, or 3 weeks at 18°C (Carré and Carré, 1991; **Figure A-5**).

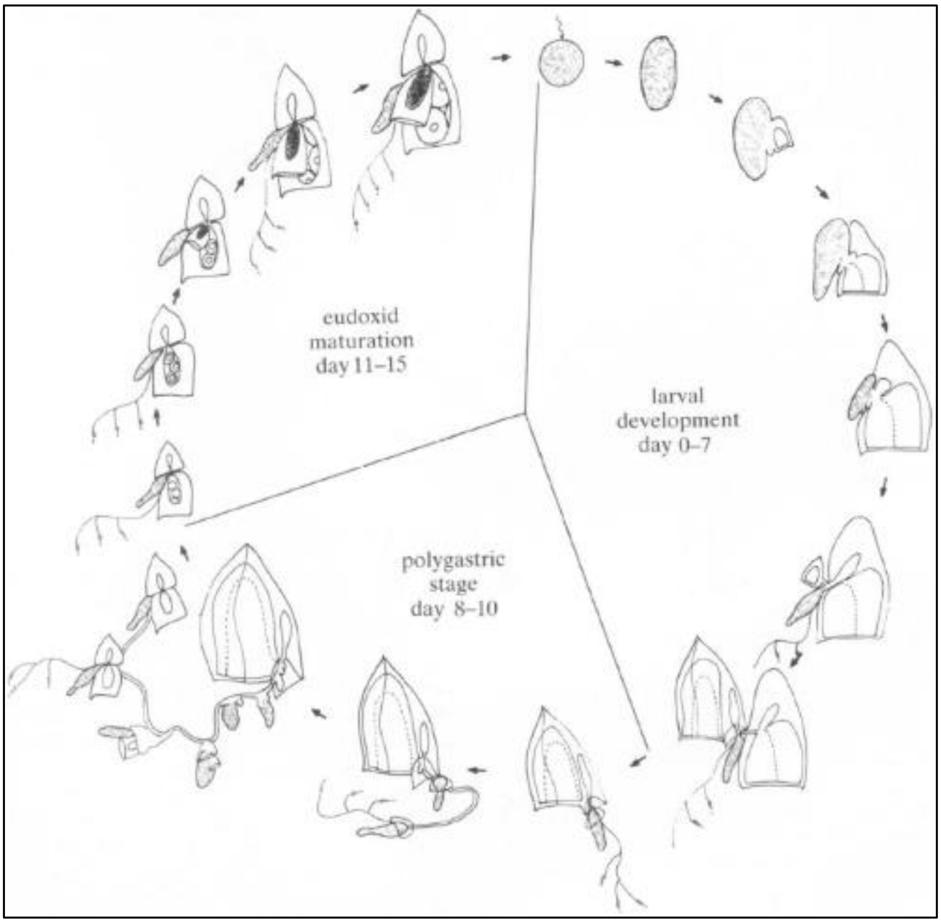

Figure A-5. Life cycle of siphonophores (From: Carré and Carré, 1991).

A.1.3.3.2 Metagenic Hydromedusae and Jellyfish

The generation time for metagenic hydromedusae and jellyfish is highly variable, ranging from a few weeks to several weeks, depending on temperature, salinity, daylight, and other environmental conditions. The life cycle of metagenic hydromedusae and jellyfish is depicted in **Figure A-6**. Potential development on floating debris of the benthic form (polyp) should be taken into consideration.

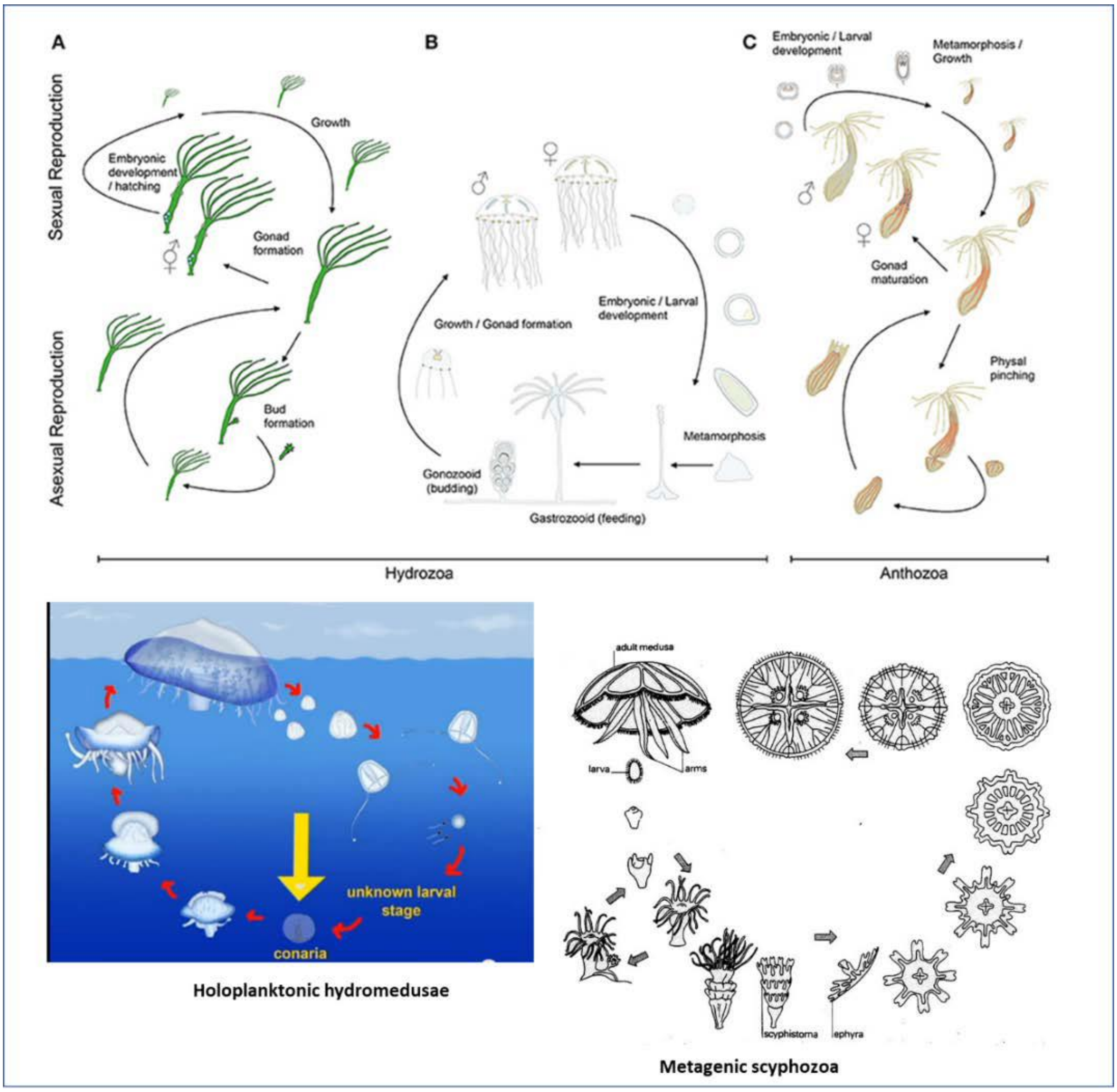

Figure A-6. Life cycle for metagenic hydromedusae and jellyfish (From: Leclère and Röttinger (2016), (top); Vidamarina (2021) (bottom left); Matveev et al. (2012) (bottom right).

A.1.3.4.1 Salps and Doliolids

The generation time for salps can be as long as nine months (Loeb and Santora, 2012) or as short as two days (Heron, 1972). Salps and doliolids have an obligatory alternation of generations with 2 or 3 stages, respectively: the solitary phase (asexual oozoid) and the colonial phases (blastozooid-sexually reproducing and phorozooid-only in doliolids). All stages can live at the same time.

A.1.3.5 Pyrosomes

Pyrosomes do not have a larval stage and the colony grows throughout their life span.

A.1.4 Question 4: What factors, if known, drive neuston "blooms?"

Brandon: For some drifting organisms, the blooms may be nothing more than currents and winds accumulating them in one spot. The swarms, or blooms, of salps are due to a life cycle that allows them to be highly adapted to patchy, unpredictable food sources. When there is little food around, their alternation of generations and hermaphroditism allows them to maintain genetic variability and to exist without reproducing in times of low food (Alldredge and Madin, 1982). But when they come across abundant food sources, their high growth rate, short generation time, high fecundity, direct development, maternal nutrition of both the embryos and the stolons, efficient morphology and alternation of generations all combine to allow for population explosions (Alldredge and Madin, 1982).

Thibault: Aggregations of neuston rather than blooms are usually the result of a combination of one or more different forcing mechanisms, including:

a) large scale and mesoscale hydrographic processes involved in the horizontal distribution such as fronts, eddies, marine currents, Ekman transport and upwelling filaments;
b) winds (epineuston more exposed to wind constraints);
c) bottom depth;
d) sea surface temperature (will play a role in generation time, metabolic and survival rates);
e) sea surface salinity (low salinity following rain or in coastal region river inflow can limit the presence of taxa such as some siphonophores);
f) food availability; neuston species are mostly carnivorous as conditions in that ecotone in term of light intensity and temperature usually drives phytoplankton further down the water column;
g) ontogenic cycle;
h) day/night cycle (endogenous cycle linked to light cycle, predation avoidance, energy conservation, genetic mixing);
i) moon phase (diel migration is limited at night during full moon, less organisms reaching the neuston layer); and/or
j) damaging ultraviolet (UV) radiation protection.

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