

**Evaluation of impacts on Pacific herring and other forage fish  
from proposed Trans Mountain Pipeline Expansion Project**

Prepared for Raincoast Conservation Foundation  
by Dr. Caroline H. Fox

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## 1 **1. Introduction**

2 This report consists of a review and critique of Trans Mountain Pipeline ULC’s Application,  
3 herein also referred to as the “Application”, for the Trans Mountain Expansion Project as it  
4 relates to Pacific herring and other forage fish. This report should not be considered exhaustive  
5 in its coverage of all project-related impacts to Pacific herring, other forage fishes and their  
6 habitats. With constraints of time, a focus is given to information deficiencies, methodological  
7 deficiencies, and potential project-related impacts to Pacific herring and their habitats within the  
8 Marine Regional Study Area (RSA).

9 The evidence in this section was prepared by Dr. Caroline Fox. Dr. C. Fox is an expert on  
10 Marine Biology, Marine Ecology, and Conservation Biology, including Pacific herring and  
11 assessments of anthropogenic threats. Dr. C. Fox has over 10 years of experience working in  
12 academic and non-governmental organizations. Currently, Dr. C. Fox is a Postdoctoral Fellow in  
13 the Department of Geography, University of Victoria and Raincoast Conservation Foundation.  
14 Her PhD research related to Pacific herring spawn events and the various ecological interactions  
15 with marine, intertidal and terrestrial ecosystems. She also sits as an alternate member on the  
16 Department of Fisheries and Oceans’ Integrated Herring Harvest Planning Committee (IHHPC).

### 17 **1.1 Pacific Herring and and Other Forage Fishes**

18 Forage fishes are crucial components of coastal marine ecosystems. Situated in the mid trophic  
19 levels, forage fishes represent a vital link between the bottom and the top of the foodweb (Pikitch  
20 *et al.* 2012). As a major prey species, a key ecological function of forage fishes is to support  
21 upper level predators, including marine birds, mammals, and fishes, such as salmon. In the Salish  
22 Sea, including the Marine RSA, the forage fish guild is made up of a number of species,  
23 including eulachon (Fraser River population; Endangered, COSEWIC 2011), surf smelt, Pacific  
24 sand lance and Pacific herring. Pacific herring, selected by the proponent and its consultants as  
25 an indicator species, are a highly interactive or “foundation” species (Soulé *et al.* 2003) and the  
26 dominant forage fish not just in the Salish Sea, but also throughout BC’s coastal waters  
27 (Schweigert *et al.* 2010). As such, they make substantial contributions to the diets of upper  
28 trophic level marine predators in coastal BC (Schweigert *et al.* 2010).

### 29 **1.2 Application Consideration of Pacific Herring and Other Forage Fishes**

30 Given the relatively poor information base regarding Pacific herring and other forage fishes that  
31 inhabit the Marine RSA, it was not unexpected that the proponent’s Application similarly  
32 suffered from poor baseline information regarding these fishes. In turn, this relative lack of  
33 information impacted the proponent and its consultants’ abilities to effectively use Pacific  
34 herring as an indicator species and to adequately assess project-related effects on Pacific herring.  
35 Further, even when existing information was available (e.g., Exxon Valdez Oil Spill (EVOS))

1 related publications), the proponent and its consultants' inclusion of this information was  
2 typically limited. Significantly, errors of omission were common throughout the Application,  
3 with the proponent and its consultants either failing completely or failing to adequately  
4 incorporate all existing habitat disturbances and potential project-related effects on Pacific  
5 herring. Collectively, these flaws tended to obscure, underestimate, or ignore potential project-  
6 related effects on Pacific herring and other forage fishes.

## 7 **2. Pacific Herring: Indicator Species for Marine Fish and Habitat**

8 Pacific herring was selected as one of six indicator species or habitats to represent the “potential  
9 effects from Project-related increased marine vessel traffic on marine fish and fish habitat”  
10 (A3S4X8). These indicators were selected based on a number of criteria, including the species  
11 having an established baseline information on biology, distribution and abundance along the  
12 shipping lanes and adjacent waters, their ecological and socio-economic importance, and others.

### 13 **2.1 Information Limitations and Deficiencies**

14 One of the criteria used by the proponent and its consultant Stantec to select indicator species  
15 was the species had “an established baseline information in biology, population abundance and  
16 distribution” (A3S4J5). The rationale provided for the selection of Pacific herring included five  
17 criteria; an established baseline of information in biology, population abundance and distribution  
18 was not listed as a rationale for selection (A3S4J5). However, the proponent and its consultant  
19 provided baseline information regarding Pacific herring and habitats that was selective and  
20 served to inaccurately portray the health of herring populations in the Marine RSA.

21  
22 Given the amount of available information regarding Pacific herring populations and their trends  
23 in the Salish Sea, which includes information regarding herring life-histories (e.g., Hay 1985),  
24 annual adult biomass estimates, population trends (e.g., DFO 2014) and archaeological evidence  
25 (e.g., McKechnie et al. 2014), the baseline information provided by the proponent was selective.  
26 The proponent stated that Pacific herring abundance reached a “historical high in 2003”  
27 (A3S4X9) but failed to explain that the baseline for this information is relatively short-term  
28 (since ~1950s), that herring biomass estimates are often highly uncertain with large confidence  
29 intervals (e.g., DFO 2014), and that deep-time baselines and oral history both suggest that Pacific  
30 herring abundance in BC, including the Salish Sea, were greater before the onset of commercial  
31 harvesting (McKechnie et al. 2014). This selective provision of information provided an  
32 inaccurate description of the health of herring populations in the Canadian portion of the Salish  
33 Sea that lies within the Marine RSA. As acknowledged in a different section however, several  
34 US Pacific herring stocks in the Marine RSA were depressed, in severe decline, critical condition  
35 and/or disappeared, in addition to several being considered healthy (A3S4X9).

36  
37 Herring was selected as an indicator species based on five stated criteria, one of which was that  
38 “DFO Important Areas for Pacific herring overlap with the shipping lanes” (A3S4J5). This

1 information regarding important areas for Pacific herring is incomplete for the region; no  
2 important areas in the US were mapped and no equivalent information was available for US  
3 waters. This information was also provided without explanation or description of its source,  
4 other than a reference. In addition to being spatially limited, the ‘DFO Important Areas’ for  
5 Pacific herring were generated by four DFO employees or former employees who drew on paper  
6 maps, which were subsequently digitized (DFO 2012). Although this information indeed reflects  
7 “expert opinion” and is considered by the proponent to be “best-available information”  
8 (A3Y3C0), it is overall reflective of the limited knowledge base regarding Pacific herring  
9 distribution and important habitats, with exception to spawning grounds.

## 10 **2.2 Deficiencies in Methodology: Measurement Endpoints**

11 The proponent’s consultant Stantec used measurement endpoints that were intended to “facilitate  
12 quantitative or qualitative measurement of potential residual and cumulative effects, and provide  
13 a means to determine the level or amount of change to an indicator” (A3S4J5). Measurement  
14 endpoints are essentially certain factors, such as length of shoreline impacted or potential for fish  
15 mortality, that allow qualitative or quantitative measurement of potential project-related effects  
16 to a given indicator. The proponent’s consultant stated that “the key issue for marine fish and  
17 fish habitat is the potential for wake waves generated by Project-related tankers and tugs to  
18 disturb intertidal habitats and potentially injure or kill” marine fish, including Pacific herring. In  
19 terms of potential environmental effects and measurement endpoints, the proponent’s consultants  
20 identified (1) disturbance to marine fish due to vessel wake (indicator = intertidal habitat), (2)  
21 injury or mortality of marine fish due to vessel wake (indicator species = Pacific herring and  
22 Pacific salmon) and (3) auditory injury or sensory disturbance to marine mammals due to  
23 underwater noise (indicator species = three marine mammals; A3S4J5).

24  
25 The potential for underwater noise impacts on marine fish was excluded from the proponent’s  
26 measurement endpoints framework. Although there is relatively limited information available in  
27 the scientific literature on this topic, underwater noise has been documented to affect fish (e.g.,  
28 avoidance response in Pacific herring; Schwarz and Greer 1984). Citing the lack of knowledge in  
29 the area, the proponent excluded any meaningful evaluation of potential residual and cumulative  
30 effects arising from project-related underwater noise on Pacific herring and salmon. By  
31 excluding this potential effect, the proponent has not accounted for all pathways of potential  
32 environmental effects. Further, by not accounting for all pathways of potential environmental  
33 effects, the proponent’s assessment of risks is incomplete and may serve to minimize potential  
34 project-related effects. More on the issue of underwater noise is included elsewhere in this  
35 document (Section 3.1).

36  
37 In addition to underwater noise being excluded as a potential project-related environmental  
38 effect, small, more frequently occurring discharges of oil (i.e., chronic oil spills) were also  
39 excluded as a potential project-related effect. More on the issue of chronic oil spill is included  
40 elsewhere in this document (Section 3.2), but in terms of potential environmental effects to the

1 selected indicator species Pacific herring, chronic oil spills should have been included as it poses  
2 potential for injury and mortality. Further, the exclusion of chronic oil as a potential  
3 environmental effect, in terms of Pacific herring and qualitative measurement endpoints, is  
4 another example of the proponent’s failure to account for all potential avenues of potential harm.  
5 As described here, the failure to incorporate chronic oil spills with regard to potential  
6 environmental effects and measurement endpoints with regard to Pacific herring may serve to  
7 minimize potential project effects.

8 **2.3 Deficiencies in Methodology: Biological Sensitivity Factors and the Assumption of**  
9 **Habitat Exposure**

10 In Stantec’s Preliminary Quantitative Ecological Risk Assessment (PQERA), the Biological  
11 Sensitivity Factors (BSF) for marine fish and habitats were based on several statements and  
12 assumptions. First, the consultant identified two major mechanisms of toxicity to fish: non-polar  
13 narcosis and blue sac disease. Although the consultant acknowledged that the marine fish  
14 community is comprised of a diversity of species and that each species has its own sensitivity to  
15 hydrocarbon exposure, for the non-polar narcosis mode of action the consultant stated that, “it is  
16 usual to consider the toxicity of hydrocarbons to a sensitive species, defined as representing the  
17 5th percentile on a species sensitivity distribution”. Assuming the “synthetic sensitive species is  
18 the same regardless of the specific habitat under consideration, the sensitivity of the community  
19 becomes a function of the degree of exposure of the particular habitat to dissolved hydrocarbons”  
20 (A3S4K7).

21  
22 When asked in an Information Request (IR) to provide supporting scientific evidence for the  
23 assumption and subsequent determination that the sensitivity of marine fish and associated  
24 habitat is a function of the degree of exposure of the particular habitat to dissolved hydrocarbons  
25 (IR1.15b, A3W7J7), the proponent simply referred back to the application, stated that in the  
26 absence of exposure a toxicological response will not be induced, and reiterated their marine  
27 habitat classification scheme regarding BSF values (Response to IR1.15b, A3Y3C0).

28  
29 The scientific evidence provided by the proponent and its consultant to justify their assumption  
30 that the sensitivity of marine fish and associated habitat is a function of the degree of exposure of  
31 the particular habitat to dissolved hydrocarbons was limited in the application and absent from  
32 their follow-up response to the IR (A3Y3C0), which is concerning. In the absence of a detailed  
33 explanation, it appears that the proponent and its consultant borrowed their approach from a  
34 single scientific source relevant to non-polar narcosis and we note that blue sac disease was not  
35 addressed.

36  
37 In our view, little scientific evidence exists to support the proponent and its consultant’s  
38 assumption regarding the sensitivity of the community being a function of the degree of exposure  
39 of a given habitat. Such an assumption is overly simplistic and not established in the scientific  
40 literature. The consultant itself acknowledged that “[t]he marine fish community is assumed to

1 comprise a wide variety of species, each of which has its own sensitivity to hydrocarbon  
2 exposure” (A3S4K7). Examples in the scientific literature have also clearly demonstrated that  
3 species and communities have varying sensitivities to oil (e.g., Rice et al. 1977). Therefore, the  
4 reliance on this assumption in the PQERA may act to minimize and/or inaccurately estimate  
5 potential project-related effects on species and their habitats.

#### 6 **2.4 Deficiencies in Methodology: Failure to Assess Subsurface Oil**

7 Subsurface oil and its potential environmental impacts on relevant wildlife receptors, including  
8 Pacific herring, were largely excluded from the PQERA, with amount of dissolved oil only  
9 granted “limited use” (A3S4K7). This omission of subsurface oil from the PQERA is concerning  
10 because without explicit inclusion and modeling of subsurface oil fates, not all potential  
11 mechanisms for oil exposure have been evaluated. As noted by French-McCay (2004), in  
12 addition to surface oil, subsurface oil and dissolved hydrocarbons must be simulated in oil fates  
13 models in order to assess exposure of marine wildlife to oil hydrocarbons. As an example, the  
14 *North Cape* oil spill resulted in most of the oil being “entrained into the water column by heavy  
15 surf, resulting in high concentrations of dissolved components in shallow water that killed  
16 millions of water column and benthic organisms” (McCay 2003).

### 17 **3. Pathways for Potential Environmental Effects**

18 The proponent and its consultants outlined existing habitat disturbances and considered several  
19 potential project-related environmental effects with respect to Pacific herring and other forage  
20 fish. Several, such as underwater noise, were only minimally considered with respect to marine  
21 fish in the project area. Others, such as chronic oil spills, were not considered an existing habitat  
22 disturbance nor were chronic oil spills considered a potential pathway for environmental effects  
23 to marine fishes. Lastly, in terms of larger spills, the proponent and its consultants make the  
24 unsupported claim that, following a worst-case oil spill scenario, Pacific herring would recover  
25 within 1-2 years.

#### 26 **3.1 Underwater Noise**

27 Although the much of the attention regarding the impacts of human-generated underwater noise  
28 on marine wildlife has focused on marine mammals, similar concerns have been raised about the  
29 effects of underwater noise on fish. The proponent identified potential effects of anthropogenic  
30 noise on fish as including physical injury, mortality, and behavioural responses (A3S4Y3).  
31 However, proponent wrote that “[e]xisting information indicates that noise levels from vessel  
32 traffic are not likely to cause physical injury or mortality to marine fish” (Popper and Hastings  
33 2009), “therefore, physical injury and mortality were not considered further in this assessment.  
34 Underwater noise from vessel traffic could, however, potentially trigger behavioural responses  
35 by marine fish. Consequently, this potential effect was considered for inclusion in the  
36 assessment” (A3S4Y3).

1  
2 The proponent’s inclusion of this potential effect with respect to marine fish in the Marine RSA  
3 was restricted to referencing a single study relating to Pacific herring responses to vessels  
4 (Schwarz and Greer 1984) and the statement regarding the lack of evidence regarding vessel  
5 traffic resulting in large-scale displacement of fish. The proponent also cited the existing overlap  
6 between fish (salmon and herring) migration areas and areas of high shipping activity as  
7 evidence that large-scale displacements had not occurred. For these reasons and “according to  
8 the judgment of the assessment team, behavioural disturbance to marine fish and invertebrates  
9 due to underwater noise from vessel traffic was not considered further in this assessment”  
10 (A3S4Y3).

11  
12 The fact that the proponent has chosen to focus on large-scale displacement of fish as the only  
13 possible negative effect of underwater vessel noise is problematic, as there exist other  
14 documented behavioural responses to underwater noise. Although the proponent is correct in  
15 stating that there is a lack of evidence in the literature showing that vessel traffic will result in  
16 large-scale displacement of fish populations, the proponent has failed to include other scientific  
17 evidence that demonstrates that underwater noise may cause behavioural changes, such as  
18 avoidance responses, and/or sublethal consequences to fish, such as cardiovascular disturbances  
19 (e.g., Engås et al. 1995, Graham and Cooke 2008, and reviewed by Slabbekoorn et al. 2010,  
20 Whitfield and Becker 2014). It should also be noted that avoidance behaviours might not result  
21 in large-scale displacement of fish populations. The lack of inclusion of relevant information  
22 regarding fish responses to underwater noise caused by the project is troubling and in this  
23 example, may have served to minimize potential project-related effects.

### 24 **3.2 Chronic Oil Spills**

25 Chronic oil spills, also referred to as chronic oil discharges, are smaller (here defined as  
26 <1000L), more frequently occurring releases of oil in the environment. Cumulatively, these  
27 chronic small discharges of oil contribute more oil to marine environments than the larger,  
28 catastrophic oils spills (National Research Council 2003). Still poorly documented in terms of  
29 specific impacts to Pacific herring and other forage fish, chronic oil spills have been  
30 demonstrated to have greater cumulative impacts on marine wildlife than the larger, less frequent  
31 oil spills (e.g., marine birds; Wiese and Robertson, 2004). Due to the documented responses of  
32 Pacific herring and other fishes to chronic exposures of oil, with examples including  
33 malformations, genetic damage, and mortality in larval pacific herring following exposure of  
34 eggs to weathered crude oil (Carls et al. 1999) and increased levels of polyaromatic hydrocarbon  
35 concentrations in Atlantic cod chronically exposed to oil (Aas et al. 2000), even relatively small  
36 discharges of oil pose a substantial risk to Pacific herring, other forage fish and marine  
37 ecosystems in the Marine RSA.

38  
39 Although the proponent claimed that they were unable to “provide a comprehensive description  
40 of oil spill conditions in the Marine RSA” (Response to IR1.10b, A3Y3C0), relatively detailed

1 evidence was available to the proponent and its consultants regarding the distribution and  
2 frequency of numerous chronic oil spills (<1000L) in the Marine RSA and surrounding waters  
3 (e.g., Serras-Sogas et al. 2008, O'Hara et al. 2009). Oiled bird carcasses and oiled beaches  
4 documented by O'Hara et al. (2009) also clearly indicate that marine wildlife and intertidal  
5 habitat, very likely including habitats used by forage fish, are impacted by chronic oil spills in  
6 the Marine RSA and surrounding waters.

7  
8 The proponent's failure to include chronic oil spills as an existing habitat disturbance to marine  
9 wildlife in the Marine RSA represents a substantial omission and serves to minimize the existing  
10 hazards that negatively impact wildlife and their habitats in the Marine RSA. Further, harm to  
11 Pacific herring and other forage fish via project-associated chronic oil spills was not identified by  
12 the proponent as a potential project-related effect, which represents another substantial omission  
13 and may serve to minimize potential project-related effects.

14  
15 When asked to justify why the ecological effects of small discharges of oil likely to occur with  
16 Project-related marine traffic was not included in the submission, the proponent stated that  
17 "[c]umulative ecological effects of small discharges of oil (< 15 mg/L hydrocarbon) were not  
18 considered as a residual effect because effective compliance monitoring and enforcement of  
19 existing legislation (which is designed to protect the marine environment) should prevent  
20 cumulative effects" (Response to IR1.10a, A3Y3C0). This response is misleading and represents  
21 an unsubstantiated opinion not supported by scientific evidence. First, the small oil discharges  
22 reported in the Marine RSA and surrounding waters by Serras-Sogas et al. (2008) were  
23 considered illegal and we note that chronic oil spills may be legal or illegal and intentional or  
24 accidental. Second, the statement that small, legal (<15mg/L) discharges of oil will not cause  
25 residual effects because compliance monitoring and enforcement of existing legislation "should"  
26 prevent cumulative effects is an unsubstantiated opinion.

### 27 **3.3 Recovery from Oil Spills**

28 In the PQERA, the proponent's consultant Stantec relied on the EVOS, as it was a good example  
29 of the effects of a large crude oil spill on various aspects of the marine environment and was  
30 particularly relevant to the proponent's project area. Concerns with the consultant's review of the  
31 EVOS and its implications for the proponent's project included: (1) their reliance on only four  
32 EVOS-focused scientific publications to evaluate the recovery potential of marine fish and  
33 habitats, (2) problematic interpretation of Pacific herring recovery, and (3) a focus on  
34 population-level impacts to marine fish.

35  
36 The proponent's consultant Stantec relied on just four EVOS-focused scientific sources to  
37 evaluate the potential for marine fish and marine fish habitat to recover from an oil spill in the  
38 Marine RSA (A3S4K7). Based on findings of the Exxon Valdez Oil Spill Trustee Council  
39 (EVOSTC, 2010), the consultant listed several species and communities injured and their  
40 recovery status following the EVOS (A3S4K7). Of these, the consultant listed two marine fish as

1 “recovered”, sediments as “recovering”, rockfish and subtidal communities as “very likely  
2 recovered” and *Pacific herring* as “not recovering” (emphasis ours; A3S4K7). Although the  
3 consultant admitted that there was controversy regarding the recovery assessment of Pacific  
4 herring, and cited several studies that speculated on the underlying causes of the Prince William  
5 Sound (PWS) population collapse following the EVOS, the consultant ultimately concluded that  
6 there were “no remaining ecologically significant effects” on PWS Pacific herring (A3S4K7).  
7 No scientific evidence was provided to support the consultant’s claim and no information was  
8 provided with regard to its determination of the recovery timeframe of PWS Pacific herring.  
9 Importantly, no explanation regarding the conflict between the consultants claim that there were  
10 “no remaining ecologically significant effects” on Pacific herring and the EVOSTC (2010)  
11 findings, which lists Pacific herring as “Not recovering” (EVOSTC, 2010, A3S4K7) were  
12 provided.

13  
14 Following this review, the consultant stated that “due to the generally low potential for the spill  
15 scenarios to cause wide-spread mortality of fish, recovery of the marine fish community would  
16 be expected to be rapid. Even under a worst-case outcome event where localized fish kills might  
17 be observed, it is expected that natural processes would compensate for the lost biological  
18 productivity within one to two years” (A3S4K7). The proponent also stated that the “effects of  
19 the EVOS on marine fish populations ... were either not significant to begin with, or recovery  
20 occurred within one or two years at most” (A3S4K7).

21  
22 The consultant’s interpretation of these publications and use as evidence to support their claim  
23 that “natural processes would compensate for the lost biological productivity within one to two  
24 years” (A3S4K7) potentially misrepresents and minimizes the consequences of an oil spill in the  
25 Marine RSA on Pacific herring and other forage fishes. Further, with respect to Pacific herring,  
26 the consultant’s claim that in the event of a worst-case oil spill event in the Marine RSA it would  
27 be expected that “that natural processes would compensate for the lost biological productivity  
28 within one to two years” (A3S4K7) is potentially unsound and not based on the life-history of  
29 Pacific herring. Pacific herring in the Marine RSA generally recruit to the commercially valuable  
30 adult population at age three (Schweigert et al. 2009). Theoretically, if there was an oil spill that  
31 caused significant mortality to adult, juvenile and larval herring in the Marine RSA, it would  
32 take a minimum of three years for the first generation of post-spill herring to recruit to the adult  
33 population and represents the earliest possible timeframe for “recovery” following significant  
34 mortality of adult, juvenile and larval herring.

35  
36 Upon asking the proponent to provide scientific evidence from other cold-water oil spills that  
37 might indicate that the marine fish community or marine fish habitat in the Marine RSA  
38 impacted for any period greater than two years, the proponent stated that “[h]arm to marine fish  
39 populations seems to be the exception, rather than the rule, following marine oil spills” and  
40 simply referenced subject matter in the Enbridge Northern Gateway hearings (Response to  
41 IR1.16h, A3Y3C0). We find this concerning for multiple reasons: (1) the proponent’s statement

1 appears to be unsupported opinion, (2) the proponent focuses on harm at the population-level and  
2 fails to mention harm to fish overall (e.g., genetic impacts on individuals), and (3) evidence from  
3 studies of oil spills on marine fish have indeed documented harm, here at the individual and  
4 population-level, lasting longer than two years (e.g., Teal et al. 1992, Short 2003), which  
5 contradicts the proponent’s statement, and (4) referral to subject matter in the Enbridge Northern  
6 Gateway Hearings is inadequate, in part because it has not been subjected to scientific peer-  
7 review.

#### 8 **4. Conclusions**

9 Because Pacific herring and other forage fishes represent a crucial conduit of energy and  
10 nutrients from lower trophic levels to upper level predators, such as salmon, marine birds, and  
11 mammals, it needs to be highlighted that existing threats to Pacific herring and other forage fish  
12 potentially impact other components of marine ecosystems in the Marine RSA. As such, project-  
13 related impacts to Pacific herring and other forage fishes could cause cascading effects across the  
14 foodweb, potentially including SARA-listed Marbled Murrelets and Southern Resident Killer  
15 Whales (SRKW). We also note that these pathways for impact are not restricted to population-  
16 level concerns (e.g., reduction of Pacific herring biomass affects Chinook salmon which, in turn,  
17 affects SRKW). Because certain contaminants biomagnify up the foodweb, any increased  
18 contamination of Pacific herring could potentially influence the contamination load of upper-  
19 level predators, including SRKW and other species. Lastly, because any potential project-related  
20 effects to Pacific herring and other forage fishes will occur alongside numerous anthropogenic  
21 influences (e.g. commercial extraction, climate change, pollution etc.), these potentially  
22 cascading effects need to be considered in the cumulative context in which they occur.

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# Caroline H. Fox

## CONTACT INFORMATION

Raincoast Conservation Foundation & Department of Geography,  
University of Victoria, PO Box 3060 STN CSC, Victoria, BC, V8W 3R4.

phone: +1 250 812 1956  
email: caroline@raincoast.org  
web: www.web.uvic.ca/  
~darimont/people/caroline-fox/

## EDUCATION

- Ph.D., Department of Biology, University of Victoria. Dissertation title: *Pacific herring and salmon: ecological interactions across the land-sea interface.* Victoria, BC 2009-2013
- M.Sc., Department of Biology, Case Western Reserve University. Thesis title: *Patterns of kelp lifestage diversity along intertidal height gradients.* Cleveland, OH 2004-2006
- B.Sc., Departments of Biology & Environmental Studies, University of Victoria. Victoria, BC 1998-2003

## RESEARCH

- NSERC IRDF Postdoctoral Fellow. Raincoast Conservation Foundation & Department of Geography, University of Victoria. Research title: *Marine bird-habitat relationships and spatial assessment of risk with anthropogenic activities.* Sidney & Victoria, BC 2013-Present
- Biologist and Marine Bird Program Coordinator. Raincoast Conservation Foundation. Sidney, BC 2007-2013
- Research Technician. Geoduck environmental impact project and aerial surveyor. Fisheries and Oceans Canada, Pacific Biological Station. Nanaimo & Tofino, BC 2006-2007
- Research Assistant. Marine phycology and global climate change. Bamfield Marine Sciences Centre. Bamfield, BC 2004
- Research Assistant. Marine phycology. Canadian Kelp Resources, Ltd., Simon Fraser University and Bamfield Marine Sciences Centre. Bamfield, BC 2003-2004
- NSERC Undergraduate Student. Fisheries Oceanography and Zooplankton Ecology Laboratory. University of Victoria. Victoria, BC 2003
- Research Volunteer. Coastal wolf research. Raincoast Conservation Foundation and University of Victoria. Victoria, BC 2001-2003

## TEACHING

- Instructor. Marine Population Ecology & Dynamics. Bamfield Marine Sciences Centre. Bamfield, BC 2012-2014
- Instructor. Coastal Biodiversity & Conservation. Bamfield Marine Sciences Centre. Bamfield, BC 2013
- Teaching Assistant. Marine Invertebrate Zoology. Bamfield Marine Sciences Centre. Bamfield, BC 2011-2012
- Teaching Assistant. Marine Ecology and Marine Population Ecology and Dynamics. Bamfield Marine Sciences Centre. Bamfield, BC 2010
- Teaching Assistant. Genes, Evolution and Ecology. Case Western Reserve University. Cleveland, OH 2004-2005

## SUPERVISION & MENTORING

- Mentor and supervisor to Environment Canada Science Horizons Youth Interns K. Kezes, G. Harvey and J. Robinson. Victoria, BC 2012-Present
- Project advisor to B. Proudfoot, BSc. Student, Advanced Diploma in GIS Applications, Vancouver Island University. Nanaimo, BC 2014-2015
- Leader. Field research teams (1-4 individuals). Numerous Locations 2007-2012

## REFEREED PUBLICATIONS

- **Fox, C.H.**, Huettmann, F., Morgan, K., O' Hara, P., Paquet, P.C. In prep. Ensemble modelling of marine bird diversity in the Queen Charlotte Basin, British Columbia.
- Darimont, C.T., **Fox, C.H.**, Bryan, H.B., Reimchen, T.E. Submitted. Trophic hegemony by human predators. Science.
- **Fox, C.H.**, Paquet, P.C., Reimchen, T.E. In Press. Novel species interactions: American black bears respond to Pacific herring spawn. BMC Ecology.
- Best, B., **Fox, C.H.**, Williams, R., Halpin, P., Paquet, P.C. In press. Updated marine mammal distribution and abundance estimates in British Columbia. Journal of Cetacean Research and Management.
- Favaro, B., Claar, D.C., **Fox, C.H.**, Freshwater, C., Holden, J.J., Roberts, A., UVic Research Derby. 2014. Trends in extinction risk for imperiled species in Canada. PlosOne. 9(11): e113118.

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- **Fox, C.H.**, El-Sabaawi, R., Paquet, P.C., Reimchen, T.E. 2014. Pacific herring (*Clupea pallasii*) and wrack macrophytes subsidize semi-terrestrial detritivores. *Marine Ecology Progress Series*. 495: 49-64.
- Reimchen, T.E., **Fox, C.H.**\* 2013. Fine-scale spatiotemporal influences of salmon on growth and nitrogen signatures of Sitka spruce tree rings. *BMC Ecology*. 13(1): 38. \*Authors contributed equally.
- **Fox, C.H.**, Paquet, P.C., Reimchen, T.E. 2010. Active black bear dens adjacent to a marine beach used for foraging. *Ursus*. 21(2): 195-197.
- **Fox, C.H.**, Swanson, A.K. 2007. Molecular detection of microscopic lifestages of laminarian macroalgae and comparison with adult forms along intertidal gradients. *Marine Ecology Progress Series*. 332:1-15. *Feature Article*.
- Swanson, A.K., **Fox, C.H.** 2007. Altered kelp (Laminariales) phlorotannins and growth under elevated carbon dioxide and ultraviolet-B treatments influence associated intertidal food-webs. *Global Change*. 13(8): 1696-1709.

### SELECT UNREFEREED PUBLICATIONS

- **Fox, C.H.** 2015. Pacific herring: a cornerstone of the British Columbian coast. *BC Nature Magazine*. Spring edition.
- **Fox, C.H.**, Favaro, B. 2015. Canada's species at risk rarely recover: the story behind the Plos One article. Plos One community blog pick of the month. [bit.ly/1Kf266n](http://bit.ly/1Kf266n).
- **Fox, C.H.** 2014. In peril: Canada's species at risk. Notes from the field. Raincoast Conservation Foundation.
- **Fox, C.H.** 2014. Herring for the masses, herring for all classes. Notes from the field. Raincoast Conservation Foundation.
- **Fox, C.H.**, Harvey, G. 2013. Marine bird surveys, 2005-2008: raw sightings information. Raincoast Conservation Foundation. Technical Report.
- Raincoast Conservation Foundation\*. 2012. Art for an oil-free coast, Canada's raincoast at risk. Raincoast Conservation Foundation. \***Fox, C.H.**, Contributing Author.
- Raincoast Conservation Foundation\*. 2010. What's at stake: the cost of oil on British Columbia's priceless coast. \***Fox, C.H.**, Contributing Author.
- **Fox, C.H.** 2009. Herring coast. Notes from the field. Raincoast Conservation Foundation.
- **Fox, C.H.** 2008. Tar (sands) and feathers. Notes from the field. Raincoast Conservation Foundation.
- **Fox, C.H.** 2007. Marine birds of Queen Charlotte Sound. Notes from the field. Raincoast Conservation Foundation.

### CONFERENCE PRESENTATIONS

- **Fox, C.H.**, Paquet, P.C., and Reimchen, T.E. 2014. Pacific herring provide an important spatial subsidy to nearshore and intertidal species. Canadian Society for Ecology and Evolution. Montreal, QC.
- **Fox, C.H.**, Paquet, P.C., and Reimchen, T.E. 2013. Ecological interactions between Pacific herring and black bears. Canadian Society for Ecology and Evolution. Kelowna, BC.
- **Fox, C.H.**, Paquet, P.C., and Reimchen, T.E. 2013. Ecological linkages between Pacific herring and black bears. Pacific Ecology and Evolution Conference. Bamfield, BC.
- **Fox, C.H.**, El-Sabaawi, R., Paquet, P.C., and Reimchen, T.E. 2012. Herring spawn and macrophytes provide a spatial subsidy to intertidal detritivores. Ecological Society of America. Portland, Oregon.
- Darimont, C.T., **Fox, C.H.**, Reimchen, T.E. 2012. Deep divergence in predatory behaviour between humans and natural predators: insights into ecosystem-based harvest management from the natural world. North American Congress for Conservation Biology. Oakland, California.
- **Fox, C.H.**, El-Sabaawi, R., Paquet, P.C., and Reimchen, T.E. 2012. Herring spawn events provide a spatial subsidy to intertidal detritivores. Restoration. Victoria, British Columbia.
- **Fox, C.H.**, Reimchen, T.E. 2011. Spawning salmon abundance predicts Sitka spruce growth in riparian forests of British Columbia. Western Society of Naturalists. Portland, Oregon.
- **Fox, C.H.** 2011. Spawning salmon abundance predicts Sitka spruce growth in riparian forests of British Columbia. Graduate Student Symposium, the University of Victoria. Victoria, British Columbia.
- Hessian-Lewis, M., Keeling, B., **Fox, C.H.**, Gerrard, A., Reimchen, T.E., Paquet, P.C., Salomon, A. 2011. Quantifying ecological effects of herring spawn events. Herring Workshop. Simon Fraser University, Burnaby, British Columbia.
- **Fox, C.H.** 2010. Seabirds and economy in British Columbia: the ENGO perspective. World Seabird Conference. Victoria, British Columbia.
- **Fox, C.H.** 2010. Linking marine, intertidal and terrestrial ecosystems: intertidal black bear activity and diet. Graduate Student Symposium, the University of Victoria. Victoria, British Columbia.

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- Kawai, D., O'Hara, P.D., **Fox, C.H.**, Paquet, P.C., Huettmann, F. 2010. Seasonal distribution and abundance predictions of seabirds in British Columbia using Random Forests. World Seabird Conference, Victoria, British Columbia. (Poster).
- Kawai, D., **Fox, C.H.**, Heise, K., Paquet, P.C., Huettmann, F. 2010. Accurate predictions of pelagic seabird populations with distance sampling, black boxes and public data: overcoming traditional regression models and parsimony. Pacific Seabird Conference. Longbeach, California. (Poster).
- **Fox, C.H.** 2009. Pacific herring: marine, intertidal and terrestrial linkages. Graduate Student Symposium, the University of Victoria. Victoria, British Columbia.
- **Fox, C.H.** and Swanson, A.K. 2005. The development of environmental genomic tools to identify microbial life-stages of brown algae. Case Western Reserve University. Northeast Algal Symposium. Rockland, MA.
- **Fox, C.H.** and Druehl, L.D. 2004. Vital staining suggests a novel growth pattern for *Alaria*. Simon Fraser University and Bamfield Marine Sciences Centre. Northwest Algal Symposium. Bamfield, B.C. (Poster).

### AWARDS & SCHOLARSHIPS

- NSERC IRDF Postdoctoral Fellowship. Raincoast Conservation Foundation and the University of Victoria. 2013-present.
- Arne H. Lane Graduate Fellowship in Marine Sciences. University of Victoria. 2012-2013.
- King Platt Fellowship. University of Victoria. 2012-2013.
- Edward Bassett Family Scholarship. University of Victoria. 2011-2012.
- Maureen De Burgh Memorial Scholarship. University of Victoria. 2011-2012.
- Teaching Assistant Scholarships. Bamfield Marine Sciences Centre. 2010-2012.
- President's Research Award. University of Victoria. 2009-2011.
- NSERC Post Graduate Scholarship. University of Victoria. 2009-2011.
- David & Geoffrey Fox Graduate Fellowship. University of Victoria. 2009-2010.
- University of Victoria Graduate Fellowship. 2009. (Declined).
- Graduate Assistantship. Case Western Reserve University. 2004-2006.
- Sigurd Tveit Memorial Scholarship. Bamfield Marine Sciences Centre. 2005.
- F. W. Benton Bursary. Bamfield Marine Sciences Centre. 2004.
- NSERC Undergraduate Award. University of Victoria. 2003.
- Samuel Simcoe Bursary. University of Victoria. 2003.
- Scholarship for Academic Excellence. University of Victoria. 2002.
- Golden Key Member. University of Victoria. 1998-2003.

### ADDITIONAL CONTRIBUTIONS

- Manuscript & Grant Review: Conservation and Biodiversity, Journal of Wildlife Management and Wildlife Monographs, Rendiconti Lincei - Scienze Fisiche e Naturali, National Science Foundation.
- Marine Conservation Caucus representative for the Integrated Herring Harvest Planning Committee (IHHPC). 2014-present.
- Expert for Raincoast Conservation Foundation as part of the Kinder Morgan Trans Mountain Pipeline Expansion Project Joint Panel Review. 2013-2015.
- Expert for Nature Canada and BC Nature as part of the Kinder Morgan Trans Mountain Pipeline Expansion Project Joint Panel Review. 2013-2015.
- Expert and Witness for Raincoast Conservation Foundation as part of the Enbridge Northern Gateway Pipeline Project Joint Panel Review. 2011-2013.
- Member of the Ancient Murrelet Management Team. 2011-2012.