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Use of Drugs and Pesticides by the Canadian Marine Finfish Aquaculture Industry in 2016-2018

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

This document is part of a CSAS process in support of the development of a post-deposit monitoring program for drug and pesticide use at Canadian marine finfish farms. This report focusses on the usage (number of farms treated and amount of active ingredient used) of drugs and pesticides at Canadian marine finfish farms during 2016-2018. Total Canadian marine finfish aquaculture production showed a slight decrease during these years: 148 900 t in 2016; 140 500 t in 2017; and 138 400 t in 2018. By province, 61-63% of the annual production was in British Columbia (BC), 17-20% in New Brunswick (NB), 11-17% in Newfoundland & Labrador (NL), and 4-8% in Nova Scotia (NS); production was >95% Atlantic salmon. The Government of Canada has required marine finfish farms to report their usage of drugs and pesticides on an annual basis since 2016. Data on drug and pesticide use in 2016-2018 were obtained from the National Aquaculture Public Reporting Data (NAPRD) and the Aquaculture Integrated Information System (AQUIIS). The reported drugs (applied in-feed) and pesticides (applied in bath treatments) included antibiotic drugs (oxytetracycline, florfenicol, erythromycin, ormetoprim, and trimethoprim), pest control drugs (emamectin benzoate, ivermectin, and selamectin for sea louse control; and praziquantel for parasitic worm control), and pesticides (azamethiphos and hydrogen peroxide; both for sea louse control). Individual farms used from zero to six drugs and pesticides in 2016, and zero to five in 2017 and 2018. Of the 136-152 active marine finfish farms in each year during 2016-2018, 108-128 (74-84%) used at least one drug or pesticide in each year. By province, 52-58% of treated farms were in BC, 26-30% in NB, 13-18% in NL, and 0-3% in NS. The percentage of active farms that used at least one drug or pesticide was: 83-86% in BC; 69-86% in NB; 74-95% in NL; and 0-38% in NS. Of the five antibiotic drugs reported, florfenicol was used at the most farms (47-50 farms per yr), followed by oxytetracycline (17-24 farms per yr); the other three were used by ≤5 farms per yr. BC had the largest number of farms treated with florfenicol and the highest quantity used in each year (34-35 farms per yr). The largest number of farms treated with oxytetracycline was in NB in 2016 (10 farms) and in BC in 2017 (7 farms) and 2018 (10 farms); the highest quantity used was in NL in 2016 and 2017, and in BC in 2018. Of the pest control drugs, emamectin benzoate was used at the most farms in all three years (56-70 farms per yr). BC had the largest number of farms treated with emamectin benzoate in all three years (32-38 farms per yr), while NL used the largest quantity in all three years. Ivermectin was used at 14-20 farms per yr and was only used in NB and NL, with NB having the larger number of farms treated and the larger quantity used in each year. Selamectin was used on a trial basis only (one NB farm in 2017 and one NB farm in 2018). Praziquantel was used only in NL, and only in 2016 and 2017. One other sea louse control drug, lufeneron, was used in freshwater hatcheries in BC, NB, and NL. The pesticide azamethiphos was used at 20-42 farms per yr; it was used only in NB and NL. In 2016, NB had the larger number of farms treated with azamethiphos (29 farms) and the larger quantity used; in 2017 and 2018, NB and NL had equal numbers of farms treated (20 farms each in 2016, 10 farms each in 2017), while NL used the larger quantity in both years. Hydrogen peroxide was used at 25-37 farms per yr; it was used in BC, NB, and NL. In 2016, NB had the largest number farms treated with hydrogen peroxide (14 farms) and also used the largest quantity; in 2017 and 2018, BC had the largest number of treated farms (17 in 2017; 22 in 2018) and also used the largest quantity in both years. There were differences in usage between salmon year-classes for some of the chemicals: florfenicol and ivermectin were used primarily on smolts, while emamectin benzoate and azamethiphos were used more on pre-market fish. In BC, treatments with drugs and pesticides occurred throughout the year, while in NB and NL, treatments did not occur in winter and early spring; in NS, the only treatments were in August 2016 and in June-August 2018 (all NS treatments were antibiotics). The three years of data were insufficient to discern clear inter-annual trends in drug and pesticide use.

1. INTRODUCTION

Marine finfish aquaculture in Canada occurs in the coastal zone of the Pacific and Atlantic coasts of Canada and in four provinces (Fig. 1): British Columbia (BC), New Brunswick (NB), Nova Scotia (NS), and Newfoundland & Labrador (NL). Canadian marine finfish aquaculture production is dominated by Atlantic salmon (*Salmo salar*), which represented >95% of the total quantity produced in 2016-2018.

As a result of the Government of Canada wanting to improve its regulation of the use of drugs and pesticides by the Canadian finfish aquaculture industry, the Aquaculture Management Directorate of Fisheries and Oceans Canada (DFO), in conjunction with Environment and Climate Change Canada (ECCC) and Health Canada's Pest Management Regulatory Agency (PMRA), have sought scientific advice on several aspects of chemical use by the industry, the potential for environmental exposure to the chemicals, the potential to estimate or model these exposures and impacts, and the potential for sampling and monitoring the exposures and impacts. This research document contributes to this body of advice.

The Government of Canada, through its Aquaculture Activity Regulations (AAR), requires each marine finfish net-pen farm in Canada to report on its usage of drugs and pesticides on an annual basis (DFO 2018a; Minister of Justice 2020). Drugs include antibiotics and pest control drugs, both applied in-feed. Pesticides are applied using bath treatments.

The information began to be collected by the Aquaculture Integrated Information System (AQUIIS) in 2015. The first full year of data collection was 2016 and summary tables were made public through the National Aquaculture Public Reporting Data (NAPRD) website in 2017 (DFO 2020b). Data for 2017 were made available in 2018 and 2018 data were made available in 2019.

The purpose of this document is to summarize and analyze the available data from 2016 to 2018, from the perspective of providing a context for the design of a post-deposit monitoring program for the drugs and pesticides used by the Canadian commercial marine finfish aquaculture sector for the control of diseases and pests (including parasites).

2. DRUGS AND PESTICIDES INCLUDED IN THE PUBLIC REPORTING DATA

The NAPRD summary reports for 2016-2018 include data on 11 drugs and pesticides used at marine finfish farms in Canada (Table 1). These chemicals fall into three categories:

- Antibiotic drugs: oxytetracycline hydrochloride; florfenicol; erythromycin; ormetoprim/ sulfadimethoxine (henceforth referred to as ormetoprim); and trimethoprim/sulfadiazine (henceforth referred to as trimethoprim)
- Pest control drugs: emamectin benzoate; ivermectin; selamectin; and praziquantel
- Pesticides: azamethiphos and hydrogen peroxide

The five antibiotic drugs and four pest control drugs are administered orally as in-feed medicines. The two pesticides are administered as bath treatments, using tarps or wellboats.

In addition, one other in-feed pest control drug, lufeneron (Imvixa™), may be released into the marine environment from marine salmon farms. Lufeneron has been approved for the control of sea lice in freshwater hatcheries, under the authority of a Health Canada Emergency Drug Release (DFO 2018b); it has also been used at freshwater salmonid hatcheries in Chile (McHenery 2016; JECFA 2017). Lufeneron is not approved for use at marine farms in Canada. However, it was detected in trace amounts in sediment samples collected near some NB marine

salmon farms in 2017-2018 (DFO, unpublished data); this was presumably due to release of the drug by fish that had been treated in freshwater hatcheries and then transferred to marine farms; in Chile, transfer of treated fish to sea can be no sooner than 7 d post-treatment (McHenery 2016).

Prior to making the decision to treat farmed fish with drugs or pesticides, the owner or operator of a farm must consider non-chemical alternatives (DFO 2018a). All drug treatments require a prescription by a licensed veterinarian (DFO 2018a).

In BC, farms are required to take action if sea louse numbers exceed three motile *Lepeophtheirus salmonis* per farmed fish during March-June, the period when wild juvenile salmon are outmigrating to sea (DFO 2016a, 2019a); this may require treatments with drugs or pesticides. In Atlantic Canada, there are no thresholds; the determination of the need to treat for sea lice (using drugs or pesticides) must be made by a licensed veterinarian.

Some of the drugs and pesticides used are not specifically approved for use in aquaculture in Canada. The antibiotic drug erythromycin and the pest control drugs ivermectin, selamectin, and praziquantel are registered for use on terrestrial animals in Canada, but not explicitly for aquaculture; however, they can be prescribed by a veterinarian for extra-label use in aquaculture (Burridge 2003; Burridge et al. 2010; DFO 2018b). Ivermectin has been used for sea louse control in NB since 1991 (O'Halloran & Coombs 1993); because of its long withdrawal period (180 d), it is usually only used on smolts (Roth 2000). Selamectin (structurally related to ivermectin) was used for sea louse control trials in NB in 2017 and 2018. Praziquantel was used for parasitic worm control in NL in 2016 and 2017.

Some of the drugs and pesticides that have federal registration cannot be used in all provinces. The use of ivermectin to control sea lice in BC was discontinued after 2000, when emamectin benzoate became available; however, both drugs are used for sea louse control in NB and NL. The pesticide azamethiphos cannot currently be used at BC finfish farms, but is used in NB and NL. Hydrogen peroxide is the only pesticide that can be used at BC finfish farms, but approval is required on a site-by-site basis.

Some other chemicals were reported in the AQUIIS database, but are not included in the NAPRD summary tables and are not included in the present report; these include anaesthetic drugs and disinfectants. The anaesthetic Tricaine methanesulfonate (MS-222) was reported at most (but not all) farms; this drug is routinely used during fish sampling. Reporting of disinfectant use is not required under the AAR; however, disinfectant use was reported at one BC farm in 2017 (three different products). Some other chemicals which are used at marine finfish farms, such as anti-fouling agents (for treating nets), are not reported in AQUIIS and NAPRD, and are not included in the present report.

3. MARINE FINFISH FARMING CONTEXT

As background for helping to design a monitoring program for the use of pesticides and drugs by the commercial finfish aquaculture industry in Canada, it is useful to have some understanding of how many potential releases or deposits of pesticides and drugs may need to be monitored.

Pesticide and drug releases originate from fish farms and individual net-pens (cages) on a farm. The number of releases in a specified unit of time is a function of the number of fish farms, the number of net-pens containing fish on the fish farms, the number of times each net-pen needs to be treated during the time period of interest, and the drug in question.

The location of pesticide and drug releases depends upon on where the farms and net-pens are located. This section provides a brief overview of the annual production of farmed salmon, the number of farm sites, and the location of these sites.

3.1. ANNUAL PRODUCTION OF FARMED MARINE FINFISH

Total Canadian marine salmonid aquaculture production declined by 7%, from 148 900 t in 2016 to 138 400 t in 2018 (Statistics Canada 2020), although interannual trends varied among provinces (Table 2). In BC, Atlantic salmon (*Salmo salar*) represented 95.7% of marine finfish aquaculture production in 2018, with Chinook salmon (*Oncorhynchus tshawytscha*) representing 2.7%, and sablefish (*Anoplopoma fimbria*) 1.6% (DFO 2019a). In Atlantic Canada, marine finfish aquaculture production was almost entirely Atlantic salmon, with limited production of steelhead (*O. mykiss*). Most of the marine salmonid production in each year during 2016-2018 was on the Pacific coast (61-63%), with the Atlantic coast accounting for the other 37-39%. By province, 61-63% was produced in British Columbia (BC); 17-20% in New Brunswick (NB), 11-17% in Newfoundland & Labrador (NL), and 4-8% in Nova Scotia (NS) (Table 2).

The global production of farmed salmon and trout in the marine environment (including brackish water) was estimated as 2 618 400 t in 2016, 2 754 700 t in 2017, and 2 824 900 t in 2018 (FAO 2020). Canada is the 4th largest producer of marine salmon and trout, with 5-6% of the total world production in these years. Norway is the largest producer (47-50% of the world total), followed by Chile (28-31%), and the UK (6-7%).

3.2. NUMBER OF MARINE FINFISH FARMS

There were are an estimated 328 commercial marine finfish aquaculture licenses in Canada in 2018; of these, 116 licenses (35%) were on the west coast in BC and 212 licenses (65%) were on the east coast, in NB, NS, and NL (Table 3). Of the licensed Canadian farms, less than half were active (i.e., were reported in the NAPRD) during each of the years 2016-2018: an average of 66% were active in BC; 47% in NB; 26% in NS; and 25% in NL (Table 3).

The NAPRD includes data from 152 Canadian marine finfish farms in 2016: 78 farms (51% of the Canadian total) in BC, 44 (29%) in NB, 8 (5%) in NS, and 22 (14%) in NL. The NAPRD for 2017 includes data from 162 Canadian marine finfish farms: 81 (50%) in BC, 45 (28%) in NB, 11 (7%) in NS, and 25 (15%) in NL. The NAPRD for 2018 includes data from 136 Canadian marine finfish farms: 73 (54%) in BC, 36 (26%) in NB, 8 (6%) in NS, and 19 (14%) in NL (Table 3).

The individual farms included in the NAPRD differed among years (Table 3). Out of the 180 farms included in at least one of the annual summary tables from 2016-2018 (90 in BC, 47 in NB, 13 in NS, and 30 in NL), 109 were included in all three years (63 in BC, 31 in NB, 6 in NS, 9 in NL), and 161 were included in at least two years (79 in BC, 47 in NB, 8 in NS, 27 in NL). The 2016 table included seven farms that appeared only in the 2016 table (5 in BC and 2 in NL). The 2017 table included 10 farms that appeared only in the 2017 table (4 in BC, 5 in NS, 1 in NL). The 2018 table included two farms that appeared only in the 2018 table (both in BC).

As noted above, Canadian marine finfish aquaculture production is >95% Atlantic salmon. Of the 90 BC marine farms included in the NAPRD for 2016-2018, 10 were growing other species, mostly Chinook salmon and sablefish; of these 10 farms, four used no drugs and pesticides during 2016-2018. All of the 47 NB marine sites were growing Atlantic salmon. The 13 NS marine sites were all licensed for either Atlantic salmon alone or Atlantic salmon and steelhead (and also groundfish at two sites). The 30 NL marine sites included one steelhead site in the brackish inner Bay d'Espoir area; all other NL sites in the NAPRD for 2016-2018 were growing Atlantic salmon.

3.3. LOCATIONS OF MARINE FINFISH FARMS

Commercial marine finfish farming occurs in the coastal zone on both the Atlantic and Pacific coasts of Canada, within three Fisheries and Oceans (DFO) regions and four provinces (Fig. 1). Maps and other information on marine finfish farm sites in Canada were obtained from the following sources:

- BC: DFO (2016b, 2019a)
- NB: NBDAAF (2020)
- NS: NSDFA (2020)
- NL: NLDFLR (2017, 2018, 2019a); GNL (2020)

On the Pacific coast of Canada, all of the farms are in the province of BC, within the DFO Pacific Region. On the Atlantic coast, the farms are located in the provinces of NB and NS, within the DFO Maritimes Region, and in the province of NL, within the DFO Newfoundland & Labrador Region.

The BC farms are found within inlets and bays along the mainland coast and Vancouver Island. DFO has established salmonid Fish Health Surveillance Zones (FHSZs) in BC, largely on the basis of watershed boundaries (DFO 2016b). Marine finfish farming occurs within seven FHSZs: 2-3, 2-4, 3-1, 3-2, 3-3, 3-4, and 3-5 (Fig. 2; Table 4). These large FHSZs do not function as management areas for aquaculture; however, the management of farms is coordinated within individual bays or subareas within the FHSZs.

The NB farms are confined to the southwestern area of the province, at the mouth of the Bay of Fundy. The NB Department of Agriculture, Aquaculture & Fisheries (NBDAAF) has established Aquaculture Bay Management Areas (BMAs) in this area. The boundaries of the BMAs were delineated by a combination of oceanographic, biosecurity and business considerations (Fig. 2; Table 4b). Within BMAs 1, 2a, 2b, 3a, 3b, and 3c, the stocking and harvesting of salmonids are synchronized: each of these BMAs can only be stocked in the first year of a three-year cycle and hence each area contains only one year-class of fish (although exceptions are sometimes permitted). All BMAs and individual farms must be fallowed between successive year-classes. The beginning of each three-year cycle is staggered among these BMAs such that different BMAs stock in different years: BMA 1 stocked in 2015 and 2018; BMAs 2a & 2b stocked in 2016; BMAs 3a & 3b stocked in 2014 & 2017; BMA 3c was created in 2017 and first stocked in that year (Table 4b). Stocking within each BMA can occur anytime throughout a stocking year, although stocking typically occurs in the spring or autumn. Designated stocking years do not apply to BMAs 5 and 6. BMA 5 is an isolated bay, with just one farm, which since 2015 been used exclusively for the Fundy Salmon Recovery Project, raising a maximum of 3300 wild salmon for later release into rivers (i.e., it is not operating as a commercial salmon farm). BMA 6 is designated for non-salmonid species only; however, the farms in this BMA have been inactive since 2011.

The NS farms are spread out along the coast of the outer Bay of Fundy and the Atlantic Ocean, and in Cape Breton Island (Fig. 2). Atlantic salmon farms in NS must be single-year class operations, with fallowing between successive year-classes. Aquaculture management areas can be set up in areas with multiple farm sites. Applications for new sites are anticipated for Nova Scotia in the near future.

The NL farms are currently confined to the Coast of Bays area, on the south coast of the Island of Newfoundland. NL implemented Bay Management Areas (BMAs) starting in 2013 (NLDFLR 2019b); maps of the BMAs were provided by C. Hendry (DFO, St John's, NL, pers. comm.). Eleven BMAs have been established for the existing marine salmon growout area (Fig. 2;

Table 4c). Not included in these BMAs is the brackish inner Bay d'Espoir area, used for growing steelhead. As in NB, each of the BMAs in NL can only be stocked in the first year of a three-year cycle and hence each area contains only one year-class of fish (although some exceptions have been permitted), and all farms must be fallowed between successive year-classes. BMAs 3, 7, and 11 were stocked in 2014 and 2017 (except one farm in BMA 3 was stocked in 2018 instead of 2017, and the one active farm in BMA 11 was stocked in 2014 only); BMAs 2, 5, and 9 were stocked in 2015 and 2018; BMAs 1, 4, and 8 were stocked in 2016; there were no farms stocked in BMAs 6 and 10 during 2014-2018. Most NL salmon farms are stocked in the spring, but a few have been stocked in autumn.

4. DATA SOURCES AND ANALYSIS METHODS

4.1. DATA SOURCES

The analyses conducted and reported in this document used data contained on the publicly available National Aquaculture Public Reporting Data (NAPRD) website (DFO 2020b). The information available from the NAPRD is based on raw data in the Aquaculture Integrated Information System (AQUIIS). The information in the AQUIIS database has been provided to DFO in response to the Aquaculture Activities Regulations (AAR) requirement that all fish farms must annually report the use of registered drugs and pesticides (DFO 2018a; Minister of Justice 2020); all operating farms are required to submit a report on drug and pesticide use, even if none were used.

The data files that were downloaded from the NAPRD website and used in this document were: Marine Finfish Data for 2016, 2017, and 2018. These files contain annual summaries of usage (of active ingredients) per drug and pesticide, and per reporting marine finfish farm, in each province. The 2016 NAPRD file was generated from data extracted from AQUIIS on 11 November 2017; the 2017 file was generated from data extracted from AQUIIS on 4 July 2018; and the 2018 file was generated from data extracted from AQUIIS on 22 August 2019. The AQUIIS data from which these summaries are derived are not publicly available; however, we were granted access to AQUIIS data files for the purpose of this report.

For the pest control drug lufeneron, annual usage data at freshwater hatcheries in 2016, 2017, and 2018 were also obtained from the NAPRD website (DFO 2020b). The data files used were: Land-Based and Freshwater Data for 2016, 2017, and 2018. The locations of marine farms that received smolts that had been treated with lufeneron (in hatcheries) were not reported in NAPRD and AQUIIS.

In this report, we examined drugs and pesticides in three categories: antibiotic drugs, pest control drugs, and pesticides. For each drug and pesticide, the NAPRD tables include the frequency of treatment and the total quantity (weight) of active ingredient introduced into the farm site through in-feed or bath treatments during the year. The NAPRD reports do not provide details on the treatment type, which net-pens were treated, or the timing of treatments in each net-pen.

The AQUIIS data tables have additional data that are not in the NAPRD summary tables, including: the total quantity of each product (kg of medicated feed or litres of aqueous product); the commercial product name; the treatment purpose; the start and end dates of each treatment; and the name, identification number, ownership, and location of each farm. The AQUIIS data do not identify which net-pens were treated during each treatment at a farm. For bath treatments, the AQUIIS data do not include the specific treatment method (i.e., tarps or wellboats).

The frequency of treatment represents the number of treatments that were reported for the year by farm site and chemical. According to the *Guidance for the Drugs and Pesticides Reporting Template* (DFO 2020c), a treatment is the same as a prescription, which may be a single dosing event (within one day) or over a treatment period (with consecutive or non-consecutive days). Frequency is calculated on a site basis: all treatments at the same site using a single chemical on the same day (or period of days) are considered to be one "treatment" for the purposes of calculating the frequency over the year. Unfortunately, this definition of "treatment" is somewhat ambiguous: it may be a bath treatment of a single net-pen, a series of bath treatments including the treatment of multiple net-pens on a site within a period of time (consecutive or non-consecutive days), a wellboat treatment of one of more net-pens within a period of time, or a sequence of feeding events using medicated feed within a period of time. The period of time for a treatment can be within one day or over several days. Because of this somewhat ambiguous definition, there can be inconsistencies in the way the term "treatment" is used among different products, sites, provinces, and years. For example, in some cases, a series of 1-day treatments with the same chemical within a period of a few days are combined and considered as one "treatment" (i.e., frequency = 1), while in other cases, each day's treatments are considered to be separate "treatments" (i.e., frequency = number of days when treatments occurred).

4.2. DATA QUALITY CONTROL

Farm operators are required by law to submit information that, to the best of their knowledge, is true, accurate, complete, and falls within the reporting period (DFO 2018c). A number of measures are taken by DFO staff to help ensure the data meet these criteria. The measures include a review of the data reported by facilities for inaccuracies and reporting errors, follow-up with facilities as necessary to verify and update their reports, the use of standardized reporting templates, internal verification, and analysis and review of datasets, before being published (DFO 2018c).

We conducted some additional quality control checks during the course of our analyses. One check involved the regeneration of summary statistics (in the NAPRD tables) from the raw data (in the AQUIIS tables) concerning the quantities (of active ingredients) used; we regenerated the total quantity of each drug or pesticide used by each jurisdiction and each farm from extractions of the raw data provided to us. This check identified some discrepancies between the regenerated statistics and the summary statistics contained within the publicly available summary datasets from the NAPRD. Differences between the two summaries were explored and the correct values identified.

One of the corrections involved the quantity of hydrogen peroxide used in BC in 2016. The quantities indicated in the NAPRD summary table for 2016 were values for "total aqueous product" or "total product quantity", instead of the quantity of "active ingredient". This error meant an approximately 50% difference in the quantity of hydrogen peroxide reported to be used in 2016 in BC. The proper quantities of hydrogen peroxide were reported in the NAPRD summary tables for other provinces in 2016, and for all provinces in 2017 and 2018. Another discrepancy identified was that the 2016 NAPRD table was missing data on the use of praziquantel in NL; the reason may have been because, for the six NL farms that used this drug in 2016, the "Fish Health Product" column in the AQUIIS tables indicated "other", (although, "praziquantel" was indicated in the "Active Chemical Ingredient" column). Trials using selamectin in NB in 2017 and 2018 were included in the AQUIIS database, but were not included in the NAPRD tables. In the 2018 NAPRD table, one of the BC farms had an incorrect identification number. As of early 2021, these errors had not been corrected in the NAPRD tables. However, the corrected values have been used in the analyses in the present report.

There were also some differences in the reporting of the raw data among years. The number of data entries for disease and pest control treatments in the AQUIIS databases increased from 1 593 in 2016 to 8 168 in 2017, then decreased somewhat to 5 666 in 2018. The main reasons for the increase from 2016 to 2017 were almost 10-fold increases in the number of entries for ivermectin, oxytetracycline, and florfenicol, even though the quantities of these chemicals used changed very little between these years; for each of these chemicals the increase in the number of data entries was due to increases in the number of multi-day treatments that were entered as several individual 1-d entries in the database (instead of a single data entry covering several days of treatments). The main reason for the decrease in the total number of data entries from 2017 to 2018 was a decrease in the number of data entries for ivermectin, which was likely related to a decrease in the use of this drug in 2018. These differences should not affect the summary of the quantities used per active ingredient, per farm, per year, but they do result in another source of differences in the meaning of treatments and the resolution of the temporal characterization of treatments between the years.

4.3. DATA ANALYSES

The present report analyzed the data pertaining to drugs and pesticides used for disease and pest control, and only considered the number of farms treated, quantity used (of active ingredient), treatment dates, and treatment locations. Data on treatment frequency were not used because of the ambiguity in the meaning of “treatment” in the AQUIIS data (see above).

It must be noted that the quantity of chemical used should not be interpreted as being indicative of environmental impact since each chemical has different modes of action, different toxicities and different suites of organisms and habitats that are sensitive and vulnerable to the chemical. Also, drugs and pesticides will be at least partially metabolized by the treated fish and/or degraded in the environment; therefore the quantity impacting the marine environment will be less than the treatment quantity.

Because of the differences in dosage (see Table 1) and toxicity among chemicals, it is not meaningful to compare the quantities used among different drugs and pesticides, so such comparisons have not been made. For the same reason, totals of quantities used were not reported for drug/pesticide categories or treatment types.

Data in the NAPRD and AQUIIS are reported on an annual basis, so our analyses were also conducted per calendar year. However, we recognize that the calendar year may not be the best time scale, because smolts can be transferred to marine sites (from hatcheries) at various times of the year, and the marine growout time for salmon extends beyond one year. It may be more appropriate to examine the usage of drugs and pesticides over the marine growout cycle, but this would mean different time scales for each farm (with different starting dates and varying durations).

Analyses of monthly trends in the quantities of drugs and pesticides used were based on the start dates of treatment entries reported in AQUIIS. This meant that these analyses did not account for treatments that started and ended in different months. Although most treatment entries included both start and end dates (except for about half of the treatment entries in BC in 2016), for those with start and end dates in different months, the quantity used in each month was not reported (only the total per treatment was reported). Because there were relatively few such cases, using just the treatment start dates should provide reasonable estimates of the general trends in monthly usage.

We did not conduct any extensive analyses to associate patterns in chemical use to any specific causes. However, we note that many factors may influence chemical use. Some of these are:

- *Husbandry practices*: To our knowledge husbandry practices were similar in the three years: same feeding regimes, same treatment tools, and administration procedures. This was true even though there were some changes/transfers of company ownership.
- *Net-pen types and sizes*: In Atlantic Canada (NB, NS, and NL), the predominant net-pen type at marine finfish farms is the circular net-pen, 70-150 m in circumference (most commonly 100 m), with up to 24 (100-m circumference) net-pens per farm; square net-pens have been largely phased out (Chang et al. 2014; NLDFLR 2019b). In BC, circular net-pens (up to 200 m circumference) and square net-pens (30×30 m and 40×40 m) are used, with up to 16 net-pens per farm (DFO 2016; P. Whittaker, Grieg Seafood, Campbell River, BC, pers. comm.).
- *Size of fish and year-class*: The fish on each salmon farm are of a single year-class. The salmon at marine farms are either smolts (salmon that have been in marine waters for $\leq$12 months) or pre-market fish (second year and sometimes third year fish). In BC, marine growout times for Atlantic salmon are typically 20-24 months (DFO 2016a), while on the Atlantic coast, marine growout times are slightly longer, averaging 24-25 months (Chang et al. 2014; Hamoutene 2014). During the growout period, the size of individual fish and the overall biomass will increase; the biomass will decrease once harvesting begins. Since the quantity of chemical used is usually related to the size (weight) of fish present, more chemical is usually required to treat pre-markets than similar numbers of smolts; on the other hand, some chemicals are used primarily on smolts. Chemical use on pre-market fish is also subject to the consideration of the withdrawal period required to ensure that tissue concentrations meet regulatory and market thresholds.
- *Smolt stocking times*: The times when smolts are transferred from freshwater hatcheries to marine sites differ somewhat between coasts: in BC, this generally occurs in September-December (for S0 smolts) or January-May (for S1 smolts) (P. Whittaker, Grieg Seafood, Campbell River, BC, pers. comm.); in Atlantic Canada, most smolts are transferred to marine farms in the spring (April-June; S1 smolts), with some transfers in the fall (October-December; S0 smolts), and occasionally in summer (G. Cline and R. MacDougall, DFO, St George, NB, pers. comm.). The timing of smolt transfer will affect the timing of treatments with certain chemicals, such as those that are used mostly during the first few months in seawater. On both coasts, the entire marine growout cycle (from smolt entry to harvest) is usually at the same site. However, in BC, there are some smolt-entry (nursery) sites which may hold up to 1.5 million smolts for a few months, after which most or all of the fish are moved to other marine sites for growout to harvest (DFO 2016a).
- *Fish health status*: The use of drugs and pesticides will be related to the health status of fish in net-pens and farms. This includes the presence of diseases and parasites (including sea lice). As noted above, in BC action is required to control sea lice if the number of motile lice exceeds a threshold during the wild juvenile outmigration period.
- *Differences in dosage per chemical*: The recommended dosage varies widely among chemicals, so the quantity used will also vary depending on the chemical used, which will depend on the disease or parasite of concern.
- *Treatment* type: The quantity of chemical used can vary with the treatment method. The drugs included in this reported are administered as in-feed treatments, while the pesticides are administered as bath treatments, using tarps or wellboats. Bath treatments in wellboats generally require less chemical than bath treatments using tarps.

- *Availability of chemicals*: As noted above, not all drugs and pesticides are available for use in all Canadian jurisdictions. For example, ivermectin and azamethiphos cannot currently be used in BC, and hydrogen peroxide cannot be used at all BC marine farms.
- *Oceanographic conditions*: Water temperature affects many aspects of the need to use chemicals as well as the metabolism of chemicals. Water temperatures in the Canadian marine finfish aquaculture areas were generally above the long-term normal during 2016-2018 (DFO 2017, 2018d, 2019b; NOAA 2020). Water temperatures undergo seasonal variations, which will influence temporal trends in the use of chemicals. The Pacific coast generally has warmer winter water temperatures than the Atlantic coast; this affects the length of the growout time, as well as the frequency of chemical treatments during the winter. Salinity, which is influenced by rainfall and snowpack, can also affect the frequency and timing of treatments.

5. NUMBER OF DRUGS AND PESTICIDES USED PER FARM

In this section, we examine the number of individual drugs and pesticides used per farm, the number of categories of drugs and pesticides used per farm, and the number of treatment types used per farm.

5.1. INDIVIDUAL DRUGS AND PESTICIDES

5.1.1. All drugs and pesticides

Canada

The number of Canadian marine finfish farms that reported using none of the drugs or pesticides included in this report (see Table 1) was: 24 of 152 reporting farms (16%) in 2016; 42 of 162 reporting farms (26%) in 2017; and 28 of 136 reporting farms (21%) in 2018 (Table 5). The remaining farms used at least one of the drugs or pesticides: 128 farms (84%) in 2016; 120 farms (74%) in 2017; and 108 farms (79%) in 2018 (Table 5).

The number of Canadian farms that reported using just one drug or pesticide was: 63 farms (41% of reporting farms) in 2016; 55 farms (34%) in 2017; and 52 farms (38%) in 2018 (Fig. 3). The number of farms that used exactly two drugs or pesticides was: 36 farms (24%) in 2016; 35 farms (22%) in 2017; and 34 farms (25%) in 2018. The number of farms that used exactly three drugs or pesticides was: 16 farms (11%) in 2016; 18 farms (11%) in 2017; and 13 farms (10%) in 2018. The maximum number of drugs and pesticides used per Canadian farm was six in 2016 (two farms); five in 2017 (three farms); and five in 2018 (one farm) (Fig. 3).

British Columbia (BC)

The number of BC marine finfish farms that reported using none of the drugs or pesticides was: 11 farms (14% of the 78 reporting BC farms) in 2016; 14 (17% of the 81 reporting BC farms) in 2017; and 10 (14% of the 73 reporting BC farms) in 2018 (Table 5). The remaining farms used at least one of the drugs or pesticides: 67 farms (86%) in 2016; 67 farms (83%) in 2017; and 63 farms (86%) in 2018 (Table 5).

The number of BC farms that reported using just one drug or pesticide was: 45 farms (58% of the reporting BC farms) in 2016; 42 farms (52%) in 2017; and 37 farms (51%) in 2018 (Fig. 3). The number of farms that used exactly two drugs or pesticides was: 19 farms (24%) in 2016; 20 farms (25%) in 2017; and 17 farms (23%) in 2018. The maximum number of drugs and pesticides used per BC farm was three in 2016 (three farms); three in 2017 (five farms); and four in 2018 (three farms) (Fig. 3).

New Brunswick (NB)

The number of NB marine finfish farms that reported using none of the drugs or pesticides was: six farms (14% of the 44 reporting NB farms) in 2016; 14 farms (31% of the 45 reporting NB farms) in 2017; and eight farms (22% of the 36 reporting NB farms) in 2018 (Table 5). The remaining NB farms used at least one of the drugs or pesticides: 38 farms (86%) in 2016; 31 farms (69%) in 2017; and 28 farms (78%) in 2018 (Table 5).

The number of NB farms that reported using just one drug or pesticide was: 10 farms (23% of reporting farms) in 2016; 10 farms (22%) in 2017; and seven farms (19%) in 2018 (Fig. 3). The number of farms that used exactly two drugs or pesticides was: 11 farms (25%) in 2016; nine farms (20%) in 2017; and 12 farms (33%) in 2018. The number of farms that used exactly three drugs or pesticides was: eight farms (18%) in 2016; six farms (13%) in 2017; and five farms (14%) in 2018. The maximum number of drugs and pesticides used per NB farm was six in 2016 (two farms); five in 2017 (one farm); and four in 2018 (four farms) (Fig. 3).

Nova Scotia (NS)

In NS, two marine finfish farms (25% of the eight reporting farms) in 2016 used one drug or pesticide, while the other six farms (75%) used none (Table 5 and Fig. 3). In 2017, no drugs or pesticides were used in NS. In 2018, three farms (38% of the eight reporting NS farms) used one drug or pesticide, while the other five farms (63%) used none (Table 5 and Fig. 3).

Newfoundland & Labrador (NL)

The number of NL marine finfish farms that reported using none of the drugs or pesticides was: one farm (5% of the 22 reporting NL farms) in 2016; three (12% of the 25 reporting NL farms) in 2017; and five (26% of the 19 reporting NL farms) in 2018 (Table 5). The remaining NL farms used at least one of the drugs or pesticides: 21 farms (95%) in 2016; 22 farms (88%) in 2017; and 14 farms (74%) in 2018 (Table 5).

The number of NL farms that reported using just one drug or pesticide was: six farms (27% of reporting NL farms) in 2016; three farms (12%) in 2017; and five farms (26%) in 2018 (Fig. 3). The number of farms that used exactly two drugs or pesticides was: six farms (27%) in 2016; six farms (24%) in 2017; and five farms (26%) in 2018. The number of farms that used exactly three drugs or pesticides was: five farms (23%) in 2016; seven farms (28%) 2017; and two farms (11%) in 2018. The maximum number of drugs and pesticides used per NL farm was five in all three years (two farms in 2016, two farms in 2017, and four farms in 2018) (Fig. 3).

5.1.2. Antibiotic drugs

Canada

The number of Canadian marine finfish farms that reported using no antibiotic drugs was: 85 farms (56% of reporting farms) in 2016; 96 farms (59%) in 2017; and 77 farms (57%) in 2018 (Table 5). The remaining Canadian farms used at least one antibiotic drug: 67 farms (44%) in 2016; 66 farms (41%) in 2017; and 59 farms (43%) in 2018 (Table 5).

The number of Canadian farms that reported using just one antibiotic drug was: 57 farms (38% of reporting farms) in 2016; 63 farms (39%) in 2017; and 51 farms (38%) in 2018 (Fig. 3). The number of farms that used exactly two antibiotic drugs was: six farms (4%) in 2016; three farms (2%) in 2017; and seven farms (5%) in 2018. The maximum number of antibiotic drugs used per Canadian farm was three in 2016 (four farms); two in 2017 (three farms); and three in 2018 (one farm) (Fig. 3).

British Columbia (BC)

The number of BC marine finfish farms that reported using no antibiotic drugs was: 37 farms (47% of reporting BC farms) in 2016; 41 farms (51%) in 2017; and 33 farms (45%) in 2018 (Table 5). The remaining BC farms used at least one antibiotic drug: 41 farms (53%) in 2016; 40 farms (49%) in 2017; and 40 farms (55%) in 2018 (Table 5).

The number of BC farms that reported using just one antibiotic drug was: 37 farms (47% of reporting BC farms) in 2016; 38 farms (47%) in 2017; and 34 farms (47%) in 2018 (Fig. 3). The number of BC farms that used exactly two antibiotic drugs was: three farms (4%) in 2016; two farms (3%) in 2017; and five farms (7%) in 2018. The maximum number of antibiotic drugs used per BC farm was three in 2016 (one farm); two in 2017 (two farms) and three in 2018 (one farm) (Fig. 3).

New Brunswick (NB)

The number of NB marine finfish farms that reported using no antibiotic drugs was: 30 farms (68% of reporting NB farms) in 2016; 28 farms (62%) in 2017; and 24 farms (67%) in 2018 (Table 5). The remaining NB farms used at least one antibiotic drug: 14 farms (32%) in 2016; 17 farms (38%) in 2017; and 12 farms (33%) in 2018 (Table 5).

The number of NB farms that reported using just one antibiotic drug was: 10 farms (23% of reporting NB farms) in 2016; 16 farms (36%) in 2017; and 10 farms (28%) in 2018 (Fig. 3). The number of farms that used exactly two antibiotic drugs was: one farm (2%) in 2016; one farm (2%) in 2017; and two farms (6%) in 2018. The maximum number of antibiotic drugs used per NB farm was three in 2016 (three farms); and two in 2017 and 2018 (two farms each year) (Fig. 3).

Nova Scotia (NS)

In NS in 2016, six farms (75% of the eight reporting NS farms) used no antibiotic drugs and two farms (25%) used only one. In 2017, none of the 11 reporting NS farms used any antibiotic drugs. In 2018 five farms (63% of the eight reporting NS farms) used no antibiotic drugs and the other three farms (38%) used one (Table 5 and Fig. 3).

Newfoundland & Labrador (NL)

The number of NL marine finfish farms that reported using no antibiotic drugs was: 12 farms (55% of reporting NL farms) in 2016; 16 farms (64%) in 2017; and 15 farms (79%) in 2018 (Table 5). The remaining NL farms used at least one antibiotic drug: 10 farms (45%) in 2016; nine farms (36%) in 2017; and four farms (21%) in 2018 (Table 5).

The number of NL farms that reported using just one antibiotic drug was: eight farms (36% of reporting NL farms) in 2016; nine farms (36%) in 2017; and four farms (21%) in 2018 (Fig. 3). The maximum number of antibiotic drugs used per NL farm was two in 2016 (two farms), and one in 2017 and 2018 (Fig. 3).

5.1.3. Pest control drugs

Canada

The number of Canadian marine finfish farms that reported using no pest control drugs was: 73 farms (48% of reporting farms) in 2016; 85 farms (53%) in 2017; and 73 farms (54%) in 2018 (Table 5). The remaining farms used at least one pest control drug: 79 farms (52%) in 2016; 77 farms (47%) in 2017; and 63 farms (46%) in 2018 (Table 5).

The number of Canadian farms that reporting using just one pest control drug was: 64 farms (42% of reporting farms) in 2016; 64 farms (40%) in 2017; and 55 (40%) in 2018 (Fig. 3). The number of farms that used exactly two pest control drugs was: 13 farms (9%) in 2016; 12 farms

(7%) in 2017; and eight farms (6%) in 2018. The maximum number of pest control drugs used per Canadian farm was three in 2016 (two farms); three in 2017 (one farm); and two in 2018 (Fig. 3).

British Columbia (BC)

The number of BC marine finfish farms that reported using no pest control drugs was: 43 (55% of reporting BC farms) in 2016; 43 farms (53%) in 2017; and 41 farms (56%) in 2018 (Table 5). The remaining BC farms used at least one pest control drug: 35 farms (45%) in 2016; 38 farms (47%) in 2017; and 32 farms (44%) in 2018 (Table 5).

The number of BC farms reporting using just one pest control drug was: 35 farms (45% of reporting BC farms) in 2016; 38 (47%) in 2017; and 32 (44%) in 2018 (Fig. 3). No BC farms used more than one pest control drug in any year (Fig. 3); only emamectin benzoate was available for use.

New Brunswick (NB)

The number of NB marine finfish farms that reported using no pest control drugs was: 18 farms (41% of reporting NB farms) in 2016; 25 farms (56%) in 2017; and 16 farms (44%) in 2018 (Table 5). The remaining NB farms used at least one pest control drug: 26 farms (59%) in 2016; 20 farms (44%) in 2017; and 20 farms (56%) in 2018 (Table 5).

The number of NB farms that reported using just one pest control drug was: 17 farms (39% of reporting NB farms) in 2016; 16 farms (36%) in 2017; and 13 farms (36%) in 2018 (Fig. 3). The number of farms that used exactly two pest control drugs was: nine farms (21%) in 2016; four farms (9%) in 2017; and seven farms (19%) in 2018. The maximum number of pest control drugs used per NB farm was two in all three years (Fig. 3).

Nova Scotia (NS)

No pest control drugs were used in NS in any of the three years.

Newfoundland & Labrador (NL)

The number of NL marine finfish farms that reported using no pest control drugs was: four (18%) in 2016; six (24%) in 2017; and eight (42%) in 2018 (Table 5). The remaining NL farms used at least one pest control drug: 18 farms (82%) in 2016; 19 farms (76%) in 2017; and 11 farms (58%) in 2018 (Table 5).

The number of NL farms that reporting using just one pest control drug was: 12 farms (55% of reporting NL farms) in 2016; 10 farms (40%) in 2017; and 10 farms (53%) in 2018 (Fig. 3). The number of NL farms that used exactly two pest control drugs was: four farms (18%) in 2016; eight farms (32%) in 2017; and one farm (4%) in 2018. The maximum number of pest control drugs used per NL farm was three in 2016 (two farms); three in 2017 (one farm) and two in 2018 (Fig. 3).

5.1.4. Pesticides

Canada

The number of Canadian marine finfish farms that reported using no pesticides was: 98 farms (65% of reporting farms) in 2016; 103 farms (64%) in 2017; and 83 farms (61%) in 2018 (Table 5). The remaining farms used at least one pesticide: 54 farms (35%) in 2016; 59 farms (36%) in 2017; and 53 farms (39%) in 2018 (Table 5).

The number of Canadian farms that reported using just one pesticide was: 41 farms (27% of reporting farms) in 2016; 48 farms (30%) in 2017; and 49 farms (36%) in 2018 (Fig. 3). The

number of farms that used two pesticides was: 13 farms (9%) in 2016; 11 farms (7%) in 2017; and four farms (3%) in 2018 (Fig. 3). A maximum of two pesticides was available for use in Canada in all three years.

British Columbia (BC)

The number of BC marine finfish farms that reported using no pesticides was: 67 farms (86% of reporting BC farms) in 2016; 64 farms (79%) in 2017; and 51 farms (70%) in 2018 (Table 5). The remaining BC farms used one pesticide: 11 farms (14%) in 2016; 17 farms 21(%) in 2017; and 22 farms (30%) in 2018 (Fig. 3). Only one pesticide (hydrogen peroxide) was available for use in BC in all three years.

New Brunswick (NB)

The number of NB marine finfish farms that reported using no pesticides was: 14 farms (32% of reporting NB farms) in 2016; 23 farms (51%) in 2017; and 15 farms (42%) in 2018 (Table 5). The remaining farms used at least one pesticide: 30 farms (68%) in 2016; 22 farms (49%) in 12017; and 21 farms (58%) in 2018 (Table 5).

The number of NB farms that reported using just one pesticide was 17 farms (39%) in 2016; 15 farms (33%) in 2017; and 21 farms (58%) in 2018 (Fig. 3). The number of farms that used two pesticides was: 13 farms (30%) in 2016; seven farms (16%) in 2017; and none in 2018 (Fig. 3).

Nova Scotia (NS)

No pesticides were used in NS in any of the three years.

Newfoundland & Labrador (NL)

The number of NL marine finfish farms that reported using no pesticides was: nine farms (41% of reporting NL farms) in 2016; five farms (20%) in 2017; and nine farms (47%) in 2018 (Table 5). The remaining NL farms used at least one pesticide: 13 farms (59%) in 2016; 20 farms (80%) in 2017; and 10 farms (53%) in 2018 (Table 5).

The number of NL farms that reported using just one pesticide was: 13 farms (59% of reporting NL farms) in 2016; 16 farms (64%) in 2017; and six farms (32%) in 2018 (Fig. 3). The number of farms that used two pesticides was: none in 2016; four farms (16%) in 2017; and four farms (21%) in 2018 (Fig. 3).

5.1.5. Sea louse control chemicals

Canada

Sea louse control chemicals used at Canadian marine finfish farms included drugs (emamectin benzoate and ivermectin; also two trials with selamectin) and pesticides (azamethiphos and hydrogen peroxide), as reported above. Up to four sea louse control chemicals were used per farm. The most common numbers of sea louse control chemicals used per farm were: zero (54-64 farms per yr; 36-41% of active farms), one (41-58 farms; 30-38%), and two (24-31 farms; 16-23%) (Table 6).

British Columbia (BC)

Two sea louse control chemicals were used in BC: the drug emamectin benzoate and the pesticide hydrogen peroxide only (see above). The number of active farms that used no sea louse control chemicals was 32-38 farms per yr (42-49% of active farms), while 28-39 farms (38-48%) used one, and 6-13 farms (8-18%) used two (Table 6).

New Brunswick (NB)

Sea louse control chemicals used in NB included drugs (emamectin benzoate and ivermectin; also two trials with selamectin) and pesticides (azamethiphos and hydrogen peroxide), as reported above. Up to four sea louse control chemicals were used per farm. The most common number of sea louse control chemicals used per farm was one (10-15 farms per yr; 28-34% of active farms), while two were used at 8-13 farms (18-36%), three were used at 4-11 farms (11-25%), and none were used at 6-15 farms (14-33%) (Table 6).

Nova Scotia (NS)

No sea louse control chemicals were used in NS during 2016-2018.

Newfoundland & Labrador (NL)

Sea louse control chemicals used in NL included drugs (emamectin benzoate and ivermectin) and pesticides (azamethiphos and hydrogen peroxide), as reported above. Up to four sea louse control chemicals were used per farm. The most common number of sea louse control chemicals used per farm was two (5-13 farms per yr; 26-52% of active farms), while 2-9 farms (8-41%) used one, 2-7 farms (9-37%) used none, and 2-6 farms (9-24%) used three (Table 6).

5.2. DRUG AND PESTICIDE CATEGORIES

Of the treated farms, some used drugs or pesticides from only one of the three categories, while others used more than one category (Tables 5 and 7). The combinations of more than one category included: antibiotic drugs and pest control drugs; antibiotic drugs and pesticides; pest control drugs and pesticides; and antibiotic drugs, pest control drugs, and pesticides.

5.2.1. Canada

In 2016, 67 of the 152 Canadian marine finfish farms reported in the NAPRD used chemicals from only one category: 30 farms used only antibiotics; 20 farms used only pest control drugs; and 17 farms used only pesticides (Table 5). Sixty-one (61) Canadian farms used drugs and pesticides from more than one category in 2016, including 50 farms that used exactly two categories and 11 farms that used all three categories (Table 7). Of the 50 farms that used exactly two categories, 24 farms used at least one antibiotic and at least one pest control drug; two farms used at least one antibiotic and at least one pesticide; and 24 farms used at least one pest control drug and at least one pesticide (Table 7).

In 2017, 57 of the 162 Canadian marine finfish farms reported in the NAPRD used drugs and pesticides from only one category: 22 farms used only antibiotics; 21 farms used only pest control drugs; and 14 farms used only pesticides (Table 5). Sixty-three (63) Canadian farms used drugs or pesticides from more than one category in 2017, including 44 farms that used exactly two categories and 19 farms that used all three categories (Table 7). Of the 44 farms that used exactly two categories, 18 farms used at least one antibiotic and at least one pest control drug; seven farms used at least one antibiotic and at least one pesticide; and 19 farms used at least one pest control drug and at least one pesticide (Table 7).

In 2018, 56 of the 136 Canadian marine finfish farms reported in the NAPRD used drugs and pesticides from only one category: 28 farms used only antibiotics, 16 farms used only pest control drugs, and 12 farms used only pesticides (Table 5). Fifty-two (52) Canadian farms used drugs or pesticides from more than one category in 2018, including 37 farms that used exactly two categories and 15 farms that used all three categories (Table 7). Of the 37 farms that used exactly two categories, 11 farms used at least one antibiotic and at least one pest control drug; five farms used at least one antibiotic and at least one pesticide; and 21 farms used at least one pest control drug and at least one pesticide (Table 7).

5.2.2. British Columbia (BC)

In 2016, 47 of the 78 BC marine finfish farms reported in the NAPRD used drugs and pesticides from only one category: 27 farms used only antibiotics; 17 farms used only pest control drugs; and three farms used only pesticides (Table 5). Twenty (20) BC farms used drugs and pesticides from more than one category in 2016: 12 farms conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; two farms conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; six farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic treatments; and none conducted at least one treatment from each of the three categories (Table 7).

In 2017, 42 of the 81 BC marine finfish farms reported in the NAPRD used drugs and pesticides from only one category in 2017: 20 farms used only antibiotics; 18 farms used only pest control drugs; and four farms used only pesticides (Table 5). Twenty-five (25) BC farms used drugs and pesticides from more than one category: 12 farms conducted at least one antibiotic and at least one pest control drug treatment, but not pesticide treatments; five farms conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; five farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic treatments; and three farms conducted at least one treatment from each of the three categories (Table 7).

In 2018, 40 of the 73 BC marine finfish farms reported in the NAPRD used drugs and pesticides from only one category: 22 farms used only antibiotics; 12 farms used only pest control drugs; and six farms used only pesticides (Table 5). Twenty-three (23) BC farms used drugs and pesticides from more than one category in 2018: seven farms conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; three farms conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; five farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic treatments; and eight farms conducted at least one treatment from each of the three categories (Table 7).

5.2.3. New Brunswick (NB)

In 2016, 12 of the 44 NB farms reported in the NAPRD used drugs and pesticides from only one category: in all 12 cases, only pesticides were used (Table 5). Twenty-six (26) NB farms used drugs and pesticides from more than one category in 2016: eight farms conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; none conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; 12 farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic treatments; and six farms conducted at least one treatment from each of the three categories (Table 7).

In 2017, 12 of the 45 NB marine finfish farms reported in the NAPRD used drugs and pesticides from only one category: one farm used only antibiotics; three farms used only pest control drugs; and eight farms used only pesticides (Table 5). Nineteen (19) of the NB farms used drugs and pesticides from more than one category in 2017: five farms conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; two farms conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; three farms conducted at least one pest control drug treatment and at least one pesticide treatment, but not antibiotic drug treatments; and nine farms conducted at least one treatment from each of the three categories (Table 7).

In 2018, eight of the 36 NB marine finfish farms reported in the NAPRD used drugs and pesticides from only one category: one farm used only antibiotics; two farms used only pest control drugs; and five farms used only pesticides (Table 5). Twenty (20) of the NB farms used drugs and pesticides from more than one category in 2018: four farms conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; two farms conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; nine farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic drug treatments; and five farms conducted at least one treatment from each of the three categories (Table 7).

5.2.4. Nova Scotia (NS)

In Nova Scotia only two of the eight farms reported in the 2016 NAPRD treated with any drugs or pesticides, and all treatments were with antibiotic drugs (Table 5). None of the 11 farms in the 2017 NAPRD used any drug or pesticide (Table 5). Three of the eight farms in the 2018 NAPRD reported using drugs or pesticides, and all three used only antibiotics (Table 5).

5.2.5. Newfoundland & Labrador (NL)

In 2016, six of the 22 NL farms reported in the NAPRD used drugs and pesticides from only one category: one farm used only antibiotics; three farms used only pest control drugs; and two farms used only pesticides (Table 5). Fifteen (15) of the NL farms used drugs and pesticides from more than one category in 2016: four farms conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; none conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; six farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic treatments; and five farms conducted at least one treatment from each of the three chemical categories (Table 7).

In 2017, three of the 25 NL farms reported in the NAPRD used drugs and pesticides from only one category: one farm used only antibiotics; no farms used only pest control drugs; and two farms used only pesticides (Table 5). Nineteen (19) of the NL farms used drugs and pesticides from more than one category in 2017: one farms conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; none conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; 11 farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic treatments; and seven farms conducted at least one treatment from each of the three chemical categories (Table 7).

In 2018, five of the 19 NL farms reported in the NAPRD used drugs and pesticides from only one category: two farms used only antibiotics; two farms used only pest control drugs; and one farm used only pesticides (Table 5). Nine of the NL farms used drugs and pesticides from more than one category in 2018: none conducted at least one antibiotic and at least one pest control drug treatment, but no pesticide treatments; none conducted at least one antibiotic and at least one pesticide treatment, but no pest control drug treatments; seven farms conducted at least one pest control drug treatment and at least one pesticide treatment, but no antibiotic treatments; and two farms conducted at least one treatment from each of the three chemical categories (Table 7).

5.3. TREATMENT TYPES

Many farms conducted treatments using both treatment types: in-feed medications (for antibiotic and pest control drugs) and bath treatments (for pesticides) (Table 8). Bath treatments are

conducted using tarpaulins (tarps) or wellboats, but the specific bath method used was not included in the databases.

5.3.1. Canada

One hundred and eleven (111) of the 128 Canadian farms that treated with at least one drug or pesticide in 2016 conducted at least one in-feed treatment (antibiotic or pest control drugs); 54 conducted at least one bath treatment (pesticides); and 37 conducted at least one in-feed treatment and at least one bath treatment (Table 8).

One hundred and five (105) of the 120 Canadian farms that treated with at least one drug or pesticide in 2017 conducted at least one in-feed drug treatment (antibiotic or pest control drugs); 59 conducted at least one bath treatment (pesticides); and 45 conducted at least one in-feed treatment and at least one bath treatment (Table 8).

Ninety-six (96) of the 108 Canadian farms that treated with at least one drug or pesticide in 2018 conducted at least one in-feed drug treatment (antibiotic or pest control drugs); 53 conducted at least one bath treatment (pesticides); and 41 conducted at least one in-feed treatment and at least one bath treatment (Table 8).

5.3.2. British Columbia (BC)

Sixty-four (64) of the 78 BC farms in the 2016 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 11 conducted at least one bath treatment (pesticides); and eight conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 64 BC farms that conducted in-feed treatments in 2016 represented 57% of the number of Canadian farms that conducted in-feed treatments; the 11 BC farms that conducted bath treatments in 2016 represented 20% of the number of Canadian farms that conducted bath treatments; and the eight BC farms that conducted both in-feed and bath treatments in 2016 represented 22% of the number of Canadian farms that used both treatment types (Table 8).

Sixty-three (63) of the 81 BC farms in the 2017 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 17 conducted at least one bath treatment (pesticides); and 13 conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 63 BC farms that conducted in-feed treatments in 2017 represented 59% of the number of Canadian farms that conducted in-feed treatments; the 17 BC farms that conducted bath treatments in 2017 represented 29% of the number of Canadian farms that conducted bath treatments; and the 13 BC farms that conducted both in-feed and bath treatments in 2017 represented 29% of the number of Canadian farms that used both treatment types (Table 8).

Fifty-seven (57) of the 73 BC farms in the 2018 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 22 conducted at least one bath treatment (pesticides); and 16 conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 57 BC farms that conducted in-feed treatments in 2018 represented 59% of the number of Canadian farms that conducted in-feed treatments; the 22 BC farms that conducted bath treatments in 2018 represented 42% of the number of Canadian farms that conducted bath treatments; and the 16 BC farms that conducted both in-feed and bath treatments in 2018 represented 39% of the number of Canadian farms that used both treatment types (Table 8).

5.3.3. New Brunswick (NB)

Twenty-six (26) of the 44 NB farms in the 2016 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 30 conducted at least one bath treatment (pesticides); and 18 conducted at least one in-feed treatment and at least one bath treatment

(Table 8). The 26 NB farms that conducted in-feed treatments in 2016 represented 23% of the number of Canadian farms that conducted in-feed treatments; the 30 NB farms that conducted bath treatments in 2016 represented 56% of the number of Canadian farms that conducted bath treatments; and the 18 NB farms that conducted both in-feed and bath treatments in 2016 represented 49% of the number of Canadian farms that used both treatment types.

Twenty-two (22) of the 45 NB farms in the 2017 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 22 conducted at least one bath treatment (pesticides); and 14 conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 22 NB farms that conducted in-feed treatments in 2017 represented 21% of the number of Canadian farms that conducted in-feed treatments; the 22 NB farms that conducted bath treatments in 2017 represented 37% of the number of Canadian farms that conducted bath treatments; and the 14 NB farms that conducted both in-feed and bath treatments in 2017 represented 31% of the number of Canadian farms that used both treatment types.

Twenty-three (23) of the 36 NB farms in the 2018 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 21 conducted at least one bath treatment (pesticides); and 16 conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 23 NB farms that conducted in-feed treatments in 2018 represented 24% of the number of Canadian farms that conducted in-feed treatments; the 21 NB farms that conducted bath treatments in 2018 represented 40% of the number of Canadian farms that conducted bath treatments; and the 16 NB farms that conducted both in-feed and bath treatments in 2018 represented 39% of the number of Canadian farms that used both treatment types.

5.3.4. Nova Scotia (NS)

All of the treatments in NS used antibiotic drugs and, hence, all were in-feed treatments (Table 8).

5.3.5. Newfoundland & Labrador (NL)

Nineteen (19) of the 22 NL farms in the 2016 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 13 conducted at least one bath treatment (pesticides); and 11 conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 19 NL farms that conducted in-feed treatments in 2016 represented 17% of the number of Canadian farms that conducted in-feed treatments; the 13 NL farms that conducted bath treatments in 2016 represented 24% of the number of Canadian farms that conducted bath treatments; and the 11 NL farms that conducted both in-feed and bath treatments in 2016 represented 30% of the number of Canadian farms that used both treatment types (Table 8).

Twenty (20) of the 25 NL farms in the 2017 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 20 conducted at least one bath treatment (pesticides); and 18 conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 20 NL farms that conducted in-feed treatments in 2017 represented 19% of the number of Canadian farms that conducted in-feed treatments; the 20 NL farms that conducted bath treatments in 2017 represented 34% of the number of Canadian farms that conducted bath treatments; and the 18 NL farms that conducted both in-feed and bath treatments in 2017 represented 40% of the number of Canadian farms that used both treatment types (Table 8).

Thirteen (13) of the 19 NL farms in the 2018 NAPRD table conducted at least one in-feed treatment (antibiotic or pest control drugs); 10 conducted at least one bath treatment (pesticides); and nine conducted at least one in-feed treatment and at least one bath treatment (Table 8). The 13 NL farms that conducted in-feed treatments in 2018 represented 14% of the number of Canadian farms that conducted in-feed treatments; the 10 NL farms that conducted

bath treatments in 2018 represented 19% of the number of Canadian farms that conducted bath treatments; and the nine NL farms that conducted both in-feed and bath treatments in 2018 represented 22% of the number of Canadian farms that used both treatment types (Table 8).

6. DRUG AND PESTICIDE USE BY JURISDICTION

6.1. CANADA

In 2016, 10 of the 11 drugs and pesticides used at marine farms (see Table 1) were used by at least one Canadian marine finfish farm; the exception was the pest control drug selamectin. In 2017, nine of the drugs and pesticides were used; the exceptions were the antibiotic drugs erythromycin and ormetoprim. In 2018, 10 of the drugs and pesticides were used; the exception was the pest control drug praziquantel (Fig. 3). The most commonly used drugs or pesticides, based on the number of farms treated, were emamectin benzoate, followed by florfenicol, in all three years (Fig. 4). As noted previously, the pest control drug lufeneron was only used at freshwater hatcheries; data on the number and locations of marine farms that may have been stocked with smolts which had been treated with lufeneron (in hatcheries) were not available from the NAPRD or AQUIIS.

The number of Canadian marine finfish farms that treated with at least one drug or pesticide was: 128 farms in 2016 (84% of Canadian farms in the NAPRD); 120 farms (74%) in 2017; and 108 farms (79%) in 2018 (Table 5). The number of Canadian marine finfish farms that treated with more than one drug or pesticide in the same year was: 65 farms in 2016 (43% of Canadian farms in the NAPRD); 65 farms (40%) in 2017; and 56 farms (41%) in 2018.

6.2. ANTIBIOTIC DRUGS

Five antibiotic drugs were used by the Canadian marine finfish aquaculture industry in 2016-2018, although three of them (erythromycin, ormetoprim, and trimethoprim) were used at only a few farms (five or less per yr). In 2016, 67 Canadian marine finfish farms treated with antibiotics (44% of Canadian farms in the NAPRD); in 2017, 66 farms (41%) treated, and in 2018, 59 farms (43%) treated (Table 5).

Antibiotic drugs were used in all four provinces in 2016 and 2018, and in all provinces except NS in 2017. Florfenicol was the most used antibiotic in Canada in terms of the number of farms treated (Fig. 4). The number of farms using florfenicol was similar in the three years, ranging from 47-50 (Fig. 5). The quantity of florfenicol used in Canada was similar in 2016 and 2017 (2705 kg and 2661 kg, respectively), but there was an increase to 4121 kg in 2018, mainly due to increased use in BC (Fig. 5). Florfenicol was used in all provinces except NS in 2016 and 2017, and in all four provinces in 2018; the highest use (in terms of number of farms treated and quantity used) was in BC in all three years, where it was used at 34-35 farms per yr (70-74% of the Canadian total) and represented 90-93% of the quantity of florfenicol used in Canada per yr (Fig. 5); florfenicol is the primary antibiotic treatment for yellow mouth disease in BC (P. Whittaker, Grieg Seafood, Campbell River, BC, pers. comm.).

Oxytetracycline was the second most commonly used antibiotic drug in Canada, in terms of number of farms treated (Fig. 4). There was a decrease in the usage of oxytetracycline in Canada, from 24 farms (13 529 kg) in 2016 to 17 farms (11 693 kg) in 2017 and 15 farms (11 097 kg) in 2018 (Fig. 5). Oxytetracycline was used in all four provinces in 2016 and 2018, and in all provinces except NS in 2017. Among the provinces, the largest number of treated farms was in NB in 2016 (10 farms; 42% of the Canadian total), and in BC in 2017 (7 farms; 41%) and 2018 (10 farms; 59%); while the largest quantity used was in NL in 2016 and 2017 (50-52% of the Canadian total), and in BC in 2018 (66%) (Fig. 5).

Erythromycin was used only in NB and NL in 2016 (one farm in each; total 232 kg); in 2017 it was not used in any province; and in 2018 it was used only in BC (one farm; 0.8 kg). Ormetoprim was used only in BC: in 2016 (three farms; 112 kg total) and 2018 (two farms; 0.1 kg total); in BC, ormetoprim has been used to treat yellow mouth disease. Trimethoprim was used only in NB (three farms; 50 kg) and NL (two farms; 174 kg) in 2016; in 2017 it was used only in NB (two farms; 34 kg); and in 2018 it was used only in NB (one farm; 28 kg).

The number of Canadian farms that treated with more than one antibiotic drug in the same year was: ten in 2016, three in 2017, and eight in 2018. The number of Canadian farms that treated with both oxytetracycline and florfenicol (the most commonly used antibiotic drugs) in the same year was: five in 2016, two in 2017, and six in 2018.

6.3. PEST CONTROL DRUGS

In all three years, pest control drugs were used in all provinces except NS. The number of Canadian farms treated with pest control drugs was 79 in 2016 (52% of Canadian farms in the NAPRD); 77 (48%) in 2017; and 63 (46%) in 2018 (Table 5). In all three years, the largest number of treated farms was in BC (32-38 farms per yr; 44-51% of treated Canadian farms), followed by NB (20-26 farms per yr; 26-33% of treated Canadian farms). Four pest control drugs were used at Canadian marine finfish farms in 2016-2018: emamectin benzoate, ivermectin, selamectin, and praziquantel.

Emamectin benzoate was the most used of the pest control drugs, in terms of the number of treated farms, in all three years (Fig. 4). There was a decrease in the number of treated farms and quantity used in Canada during 2016-2018: 70 farms (102 kg) in 2016; 61 farms (100 kg) in 2017; 56 farms (74 kg) in 2018 (Fig. 6). Emamectin benzoate was used in all provinces except NS in all three years. It was the only pest control drug used in BC, which had the largest number of treated farms in all three years (32-38 farms per yr; 44-51% of the Canadian total). NL was the largest user by quantity in all three years, with 44-57% of the Canadian total (Fig. 6).

Ivermectin was used in NB and NL, but not in BC and NS, in all three years (Fig. 6). Total usage in Canada was similar in 2016 (20 farms, 8.6 kg) and 2017 (22 farms, 8.6 kg), but declined in 2018 (14 farms, 3.3 kg) largely due to decreased usage in NL (Fig. 6). The highest usage in terms of number of treated farms and quantity was in NB in all three years, with 13-14 farms per yr (59-93% of the Canadian total) and 52->99% of the total used in Canada (Fig. 6).

Selamectin was used on a trial basis in 2017 and 2018 (one-week trials at one NB farm in each year) (Fig. 6); these trials were at farms that did not use any other pest control drug in the same year.

Praziquantel, which is used for parasitic worm control, was used only in NL, and only in 2016 and 2017 (Fig. 6). In 2016 it was used at six farms (40 kg) and in 2017 it was used at seven farms (44 kg) (Fig. 6).

Several Canadian farms used more than one pest control drug in the same year: 15 in 2016; 13 in 2017; and 8 in 2018. The number of Canadian farms that used both emamectin benzoate and ivermectin (the most commonly used sea louse control drugs) in the same year was: 11 in 2016; 7 in 2017; and 8 in 2018.

Lufeneron, which can only be used at freshwater hatcheries, was used at two Canadian hatcheries in 2016 (3.2 kg); six hatcheries in 2017 (17.6 kg); and eight hatcheries in 2018 (42.1 kg).

6.4. PESTICIDES

There are only two pesticides (applied using bath treatment) registered in Canada for sea louse control in marine net-pen finfish culture: hydrogen peroxide and azamethiphos. The Canadian industry treated with at least one pesticide at 54 farms in 2016, 59 farms in 2017, and 53 farms in 2018 (Table 5); pesticides were used in all provinces except NS in all three years.

Azamethiphos was used in NB and NL in all three years, but not in BC (where provincial regulations prohibit its use) and NS (Fig. 7). The usage of azamethiphos declined from 42 farms (859 kg) in 2016 to 40 farms (693 kg) in 2017, and 20 farms (502 kg) in 2018 (Fig. 7). The number of treated farms was highest in NB in 2016 (29 farms; 69% of the Canadian total), and equal in NB and NL in 2017 (20 farms each) and 2018 (10 farms each); usage by quantity was highest in NB in 2016 (79% of the Canadian total), and highest in NL in 2017 (55%) and 2018 (79%) (Fig. 7).

Hydrogen peroxide was used in BC and NB in 2016, and in BC, NB and NL in 2017 and 2018 (Fig. 7). The number of farms treated increased, while the quantity of hydrogen peroxide used in Canada declined somewhat during 2016-2018: 25 farms (458 314 kg) in 2016; 30 farms (439 436 kg) in 2017; and 37 farms (418 747 kg) in 2018 (Fig. 7). The highest usage (in number of treated farms and quantity used) was in NB in 2016 (56% of treated farms; 63% of quantity), and in BC in 2017 (57% of treated farms; 63% of quantity) and 2018 (59% of treated farms; 61% of quantity (Fig. 7).

Several Canadian farms used both azamethiphos and hydrogen peroxide in the same year: 13 in 2016; 11 in 2017; and 4 in 2018.

6.5. BRITISH COLUMBIA (BC)

The BC marine finfish aquaculture industry used five of the 11 drugs and pesticides listed in Table 1 in 2016, four of the chemicals in 2017, and six of the chemicals in 2018 (Fig. 4). The most commonly used drugs or pesticides, based on the number of farms treated, were florfenicol and emamectin benzoate in all three years (Fig. 4).

The number of BC farms that treated with at least one drug or pesticide in 2016 was 67 (52% of the Canadian total); in 2017, 67 farms (56%); and in 2018, 63 farms (58%) (Table 5). The number of BC farms that treated with more than one drug or pesticide in the same year was: 22 in 2016, 25 in 2017, and 26 in 2018.

6.5.1. Antibiotic drugs (BC FHSZs)

The number of BC farms treating with antibiotics was similar in the three years: 41 farms (61% of the Canadian total) in 2016; 40 farms (61%) in 2017; and 40 farms (68%) in 2018 (Table 5).

Oxytetracycline use in BC was similar in 2016 (eight farms, 2 108 kg) and 2017 (seven farms, 2 514 kg), but increased in 2018 (10 farms, 7 347 kg) (Fig. 5). BC accounted for 33% of the number of Canadian farms treated with oxytetracycline and 16% of the quantity used in Canada in 2016; 41% of the number of treated farms and 22% of the quantity used in 2017; and 59% of the number of treated farms and 66% of the quantity used in 2018. Oxytetracycline was used in four of the seven FHSZs in 2016 and 2018 (2-3, 2-4, 3-1, and 3-3), with the highest quantity used in FHSZ 3-1 in 2016 (59% of the BC total) and in FHSZ 2-3 in 2018 (59%); and in three FHSZs in 2017 (2-3, 2-4, and 3-3), with the highest quantity used in FHSZ 2-3 (87%) (Fig. 8a).

Florfenicol use in BC did not change from 2016 (35 treated farms; 2 432 kg) to 2017 (35 farms; 2 436 kg), but increased in quantity (but not in the number of treated farms) in 2018 (34 farms; 3 824 kg) (Fig. 5). In all three years, BC was the main user of florfenicol in Canada, both in

number of farms treated (70-74% of the treated Canadian farms) and the quantity used (90-93% of the total quantity used in Canada) (Fig. 5). This drug was used in all seven FHSZs in 2016 and 2017, with the highest quantity used in FHSZ 3-3 in 2016 (37% of the BC total) and in 2-3 in 2017 (34%); and in all except FHSZ 3-1 in 2018, with the highest quantity used in FHSZ 3-3 (42%) (Fig. 8a).

Erythromycin was not used in BC in 2016 and 2017, and at only one farm in 2018 (FHSZ 3-3; 0.8 kg). Ormetoprim was used at three farms in 2016 (all in FHSZ 2-3; 112 kg total); no farms in 2017; and two farms in 2018 (both in FHSZ 2-4; 0.1 kg total). Trimethoprim was not used in BC in any of the three years.

The number of BC farms that used more than one antibiotic drug in the same year was: four farms in 2016, two farms in 2017, and six farms in 2018. The number of BC farms that used both oxytetracycline and florfenicol (the most commonly used antibiotic drugs) in the same year was: two in 2016, two in 2017, and five in 2018.

6.5.2. Pest control drugs (BC FHSZs)

The only pest control drug used at marine finfish farms in BC during 2016-2018 was emamectin benzoate, which was used in all seven FHSZs in all three years (Fig. 8b). Emamectin benzoate use in BC was similar in the three years: 35 farms (21 kg) in 2016; 38 farms (25 kg) in 2017; and 32 farms (21 kg) in 2018 (Fig. 6). BC accounted for 50% of the number of Canadian farms treated with emamectin benzoate and 21% of the total quantity used in Canada in 2016; 62% of the number of treated farms and 25% of the quantity used in 2017; and 57% of the number of treated farms and 29% of the quantity used in 2017. The highest quantity used was in FHSZs 3-2 and 3-3 in 2016 (29% and 25% of the BC total) and 2018 (25% and 20%); and in FHSZs 3-3 and 2-3 in 2017 (28% and 24%) (Fig. 8b).

Lufeneron was not used in BC in 2016 and 2017, but was used at one freshwater hatchery in 2018 (5.0 kg) (Fig. 6).

6.5.3. Pesticides (BC FHSZs)

The only pesticide that was authorized for use in BC during 2016-2018 was hydrogen peroxide. However, it is not available for use at all BC farms: its use in BC is authorized on a site-by-site basis (P. Whittaker, Grieg Seafood, Campbell River, BC, pers. comm.). Hydrogen peroxide use in BC increased from 11 farms (170 851 kg) in 2016, to 17 farms (277 048 kg) in 2017, and 21 farms (256 980 kg) in 2018 (Fig. 7). BC accounted for 44% of the number of Canadian farms treated with hydrogen peroxide and 37% of the quantity used in Canada in 2016; 57% of the number of treated farms 63% of the quantity used in 2017; and 59% of the number of treated farms and 61% of the quantity used in 2018. Hydrogen peroxide was used in FHSZs 3-2, 3-4, and 3-5 in 2016, with the highest quantity used in 3-5 (58% of the BC total); in the same FHSZs plus 2-4 in 2017, with the highest quantity used in 2-4 (66%); and in all except FHSZ 3-1 in 2018, with the highest quantity used in FHSZs 2-4, 2-3, and 3-4 (24-26% in each) (Fig. 8b).

6.6. NEW BRUNSWICK (NB)

The NB industry used 7-8 of the 11 drugs and pesticides listed in Table 1 in each of the three years (Fig. 4). The most commonly used drugs or pesticides, based on the number of farms treated, were azamethiphos and emamectin benzoate in 2016; azamethiphos and ivermectin in 2017; and ivermectin and emamectin benzoate in 2018 (Fig. 4).

The number of NB farms that treated with at least one drug or pesticide in 2016 was 38 (30% of the Canadian total); in 2017, 31 farms (26%); and in 2018, 28 farms (26%) (Table 5). The

number of NB farms that treated with more than one drug or pesticide in the same year was: 28 in 2016, 21 in 2017, and 21 in 2018.

6.6.1. Antibiotic drugs (NB BMAs)

In 2016, antibiotics were used at 14 NB farms (21% of the Canadian total); in 2017 they were used at 17 farms (26%); and in 2018 they were used at 12 farms (20%) (Table 5).

Oxytetracycline was used at 10 NB farms (3 881 kg) in 2016; five farms (3 318 kg) in 2017; and five farms (3 495 kg) in 2018 (Fig. 5). NB accounted for 42% of the number of Canadian farms treated with oxytetracycline in 2016 and 29% in 2017 and 2018; and 28-31% of the quantity used in Canada during each of these years. In 2016, oxytetracycline was mostly used in BMAs 1 and 2b (48-49% of the NB total quantity in each), with 3% used in BMA 2a; in 2017 it was mostly used in BMA 2b (93%), with the other 7% used in BMA 1; and in 2018 it was mostly used in BMA 3b (97%), with the other 3% used in BMA 1 (Fig. 9a).

Florfenicol was used at seven NB farms (66 kg) in 2016; 11 farms (182 kg) in 2017; and five farms (3 495 kg) in 2018 (Fig. 5). NB accounted for 15% of the number of Canadian farms treated with florfenicol and 2% of the quantity used in Canada in 2016; 22% of the number of treated farms and 7% of the quantity used in 2017; and 17% of the number of treated farms and 5% of the quantity used in 2018. In 2016, florfenicol was mostly in BMA 2a (74% of the NB total quantity), with smaller amounts used in BMAs 2b (23%) and 1 (3%); in 2017 it was mostly used in BMA 2a (71%), with smaller amounts used in BMAs 3b (18%), 3a (6%), 2b (3%), and 3c (3%); and in 2018 it was mainly used in BMA 3b (84%), with the other 16% used in BMA 1 (Fig. 9a).

Erythromycin was used in NB at only one farm in 2016 (BMA 1; 80 kg) and was not used at any farm in 2017 or 2018. Ormetoprim was not used at any NB farm in any year. Trimethoprim was used at only three farms in 2016 (all in BMA 2a; 50 kg total); two farms in 2017 (one in BMA 2a, one in BMA 3c; 34 kg total); and one farm in 2018 (BMA 1; 28 kg).

The number of NB farms that treated with more than one antibiotic drug in the same year was: four farms in 2016, one in 2017, and two farms in 2018. The number of NB farms that treated with both oxytetracycline and florfenicol (the most commonly used antibiotic drugs) in the same year was: three farms in 2016, none in 2017, and one farm in 2018.

6.6.2. Pest control drugs (NB BMAs)

The use of pest control drugs in NB decreased from 2016 to 2018: 26 farms (33% of the Canadian total) in 2016; 20 farms in 2017 (26%) and 2018 (32%) (Table 5). The pest control drugs used at marine finfish farms in NB were emamectin benzoate and ivermectin, which were both used in all three years; and selamectin, which was used on a trial basis in 2017 and 2018.

Emamectin benzoate usage in NB decreased from 2016 to 2018: 21 farms (36 kg) in 2016; 10 farms (22 kg) in 2017; and 13 farms (11 kg) in 2018 (Fig. 6). NB accounted for 30% of the number of Canadian farms treated with emamectin benzoate and 35% of the quantity used in Canada in 2016; 16% of the number of treated farms and 22% of the quantity used in 2017; and 23% of the number of treated farms and 15% of the quantity used in 2018. Emamectin benzoate was used in BMAs 1, 2a, 2b & 5 in 2016, in BMAs 1, 2a, 2b, 3c & 5 in 2017; and in BMAs 1, 3b, 3c. and 5 in 2018 (Fig. 9b). In 2016, 77% of the total quantity used in NB was used in BMA 1; in 2017, 86% was used in BMA 2a; in 2018, 52% was used in BMA 3c. In BMA 5, which had one farm used by the Fundy Salmon Recovery Project to hold small numbers of wild salmon (maximum 3300), small quantities of emamectin benzoate were used (0.03 kg in 2016; <0.01 kg in 2017 and 2018); no other pest control drugs were used at this site in any year.

Ivermectin usage also decreased from 2016 to 2018: 14 farms (5.5 kg) in 2016; 13 farms (4.5 kg) in 2017; and 13 farms (3.3 kg) in 2018 (Fig. 6). NB accounted for 70% of the number of Canadian farms treated with ivermectin and 64% of the quantity used in Canada in 2016; 59% of the number of treated farms and 52% of the quantity used in 2017; and 93% of the number of treated farms and >99% of the quantity used in 2018. Ivermectin was used in BMAs 1, 2a & 2b in 2016; in BMAs 2a, 2b, 3a, 3b & 3c in 2017; and in BMAs 1, 3a and 3b in 2018 (Fig. 9b). In 2016, 54% of the total NB quantity was used in BMA 2b and 31% in 2a (both BMAs stocked in 2016); in 2017, 48% was used in BMA 3a and 43% in 3b (both BMAs stocked in 2017); in 2018 76% was used in BMA 1 (stocked in 2018).

Selamectin was used on a trial basis only, at one farm in BMA 2b in 2017 (0.4 kg) and at one farm in BMA 3a in 2018 (0.5 kg) (Fig. 6); in both cases, the trials were one-week in duration and were at farms that did not treat with ivermectin or emamectin benzoate in the same year.

The number of NB farms that treated with more than one pest control drug in the same year was: nine in 2016, four in 2017, and seven in 2018; in all cases these farms used both emamectin benzoate and ivermectin (the most commonly used pest control drugs).

Lufeneron was used in NB at two freshwater hatcheries in 2016 (3.2 kg); five hatcheries in 2017 (16.3 kg); and five hatcheries in 2018 (16.9 kg) (Fig. 6).

6.6.3. Pesticides (NB BMAs)

Pesticides usage in NB declined during 2016-2018: 30 farms (56% of the Canadian total) in 2016; 22 farms (37%) in 2017; and 21 farms (40%) in 2018 (Table 5). Both azamethiphos and hydrogen peroxide were used in all three years. In 2016 and 2017, about twice as many farms used azamethiphos as used hydrogen peroxide in 2016 and 2017, while in 2018 the number of farms treating with each pesticide was similar (Fig. 7).

Azamethiphos usage in NB declined during 2016-2018: 29 farms (682 kg) in 2016; 20 farms (312 kg) in 2017; and 10 farms (107 kg) in 2018 (Fig. 7). NB accounted for 69% of the number of Canadian farms treated with azamethiphos and 79% of the quantity used in Canada in 2016; 50% of the number of farms treated and 45% of the quantity used in 2017; and 50% of the farms treated and 21% of the quantity used in 2018. Azamethiphos was used in all active BMAs in 2016; in all BMAs except 3b in 2017; and in BMAs 2a, 3a, and 3b in 2018 (Fig. 9c). In 2016, 72% of the azamethiphos used in NB was used in BMA 1; in 2017, 66% was used in BMA 2a; in 2018, 70% was used in BMA 3a. The wild salmon site in BMA 5 used small quantities of azamethiphos in each year (<2 kg per yr).

Hydrogen peroxide usage in NB declined during 2016-2018: 14 farms (287 463 kg) in 2016; none farms (99 975 kg) in 2017; and 11 farms (124 740 kg) in 2018 (Fig. 7). NB accounted for 56% of the number of Canadian farms treated with hydrogen peroxide and 63% of the quantity used in Canada in 2016; 30% of the number of treated farms and 23% of the quantity used in 2017; and 30% of the number of treated farms and 30% of the quantity used in 2018. Hydrogen peroxide was used in BMAs 1, 2a & 3a in 2016; in BMAs 1, 2a, 2b & 3a in 2017; and in BMAs 1, 3b, and 3c in 2018 (Fig. 9c). In 2016, 77% of the NB usage (by quantity) was in BMA 1; in 2017, 39% was in BMA 2a and 24% in 2b; in 2018, 86% was in BMA 1).

The number of NB farms treated with both azamethiphos and hydrogen peroxide in the same year was: 13 in 2016, 7 in 2017, and none in 2018.

6.7. NOVA SCOTIA (NS)

In 2016, the NS marine finfish aquaculture industry used only one of the 11 drugs and pesticides listed in Table 1 (Fig. 4). In 2017, none of the 11 chemicals were used in NS. In 2018,

two of the 11 chemicals were used in NS (Fig. 4). Lufeneron was not used at any NS hatcheries in 2016-2018. The only drugs or pesticides used in NS during 2016-2018 were oxytetracycline and florfenicol (Fig. 4).

In 2016, two NS farms treated with at least one drug or pesticide (2% of the Canadian total). In 2017, no NS farms treated with any drug or pesticide. In 2018, three NS farms (3%) treated with at least one drug or pesticide (Table 5). No NS farms used more than one drug or pesticide in any year.

6.7.1. Antibiotic drugs (NS)

Antibiotic drugs were used at only two farms in NS in 2016: one in the Annapolis Basin (297 kg of oxytetracycline) and one in St Mary's Bay (247 kg of oxytetracycline). In 2017, no antibiotic drugs were used at any NS finfish farms. Antibiotic drugs were used at three NS farms in 2018: two of these farms treated with oxytetracycline (171 kg at one farm in the Annapolis Basin and 85 kg at one farm in St Mary's Bay) and one farm in the Annapolis Basin treated with florfenicol (17 kg); no NS farms used both oxytetracycline and florfenicol in 2018. No other antibiotic drugs were used in NS during 2016-2018 (Fig. 4).

6.7.2. Pest control drugs and pesticides (NS)

No pest control drugs or pesticides were used at marine finfish farms in Nova Scotia in during 2016-2018. Lufeneron was not used at any NS freshwater hatcheries during these years.

6.8. NEWFOUNDLAND & LABRADOR (NL)

In 2016 the NL industry used eight of the 11 drugs and pesticides listed in Table 1; in 2017 seven of the chemicals were used; and in 2018 four were used (Fig. 4). The most commonly used drugs or pesticides, based on the number of farms treated, were emamectin benzoate and azamethiphos in all three years (Fig. 4).

The number of NL farms that treated with at least one drug or pesticide in 2016 was 21 (16% of the Canadian total); in 2017, 22 farms (18%); and in 2018, 14 farms (13%) (Table 5). The number of NL farms that treated with more than one drug or pesticide in the same year was: 15 in 2016, 19 in 2017, and 9 in 2018.

6.8.1. Antibiotic drugs (NL BMAs)

The number of NL farms treating with antibiotics declined from 10 (15% of the Canadian total) in 2016, to nine (14%) in 2017, and four (7%) in 2018 (Table 5).

Oxytetracycline was used at four NL farms in 2016 (6 997 kg); five farms in 2017 (5 860 kg); and this drug was not used in 2018 (Fig. 5). NL accounted for 17% of the number of Canadian farms treated with oxytetracycline and 52% of the quantity used in Canada in 2016, and 29% of the number of farms and 50% of the quantity used in 2017. In 2016, oxytetracycline was used only in BMAs 9 (81% by quantity) and 5 (19%); in 2017, it was used only in BMAs 8 (67%) and 7 (33%) (Fig. 10a).

Florfenicol was used at five NL farms in 2016 (207 kg); four farms in 2017 (42 kg); and four farms in 2018 (72 kg) (Fig. 5). NL accounted for 10% of the number of Canadian farms treated with florfenicol and 8% of the quantity used in Canada in 2016; 8% the number of farms treated and 2% of the quantity used in 2017; and 9% of the number of farms treated and 2% of the quantity used in 2018. In 2016, florfenicol was used mainly in BMAs 1 (54% of the NL quantity) and 4 (42%); with only 4% in BMA 2; in 2017 it was only used in BMA 3; and in 2018 it was used in BMAs 3 (64%) and 5 (36%) (Fig. 10a).

Erythromycin was used at only one NL farm in 2016 (BMA 4; 153 kg), and at no farms in 2017 and 2018. Ormetoprim was not used at any NL farms in any year. Trimethoprim was used at only two farms in 2016 (both in BMA 4; 174 kg total), and at no farms in 2017 and 2018.

The number of NL farms that treated with more than one antibiotic drug in the same year was two in 2016, and none in 2017 and 2018. No NL farms used both oxytetracycline and florfenicol in any one year.

6.8.2. Pest control drugs (NL BMAs)

The number of NL farms treating with pest control drugs was 18 (23% of the Canadian total) in 2016; 19 (25%) in 2017; and 11 (17%) in 2018 (Table 5). The pest control drugs used in NL were emamectin benzoate and ivermectin, which were both used in all three years; and praziquantel, which was used only in 2016 and 2017 (Fig. 4).

Emamectin benzoate was used at 14 NL farms in 2016 (45 kg; 13 farms in 2017 (54 kg); and 13 farms in 2018 (54 kg) (Fig. 6). NL accounted for 20% of the number of Canadian farms treated with emamectin benzoate and 44% of the quantity used in Canada in 2016; 21% of the number of farms treated and 54% of the quantity used in 2017; and 20% of the farms treated and 57% of the quantity used in 2018. Emamectin benzoate was used in BMAs 1, 2, 3, 5, 8, 9, and the inner Bay d'Espoir in 2016; in BMAs 1, 2, 3, 4, 7, and 8 in 2017; and in BMAs 2 and 3 in 2018 (Fig. 10b); in 2016, the highest quantities of emamectin benzoate were used in BMAs 5 (51% of the NL total) and 2 (28%); in 2017 in BMAs 4 (41%) and 1 (35%); and in 2018 in BMA 3 (96%).

Ivermectin was used at six NL farms in 2016 (3.1 kg); nine farms in 2017 (4.1 kg); and one farm in 2018 (<0.1 kg) (Fig. 10). NL accounted for 30% of the number of Canadian farms treated with ivermectin and 36% of the quantity used in Canada in 2016; 41% of the number of farms treated and 48% of the quantity used in 2017; and 7% of the number of farms treated and <1% of the quantity used in 2018. Ivermectin was used in BMAs 1, 2, and 4 in 2016; in BMAs 3 and 7 in 2017; and only in BMA 3 in 2018 (Fig. 10b); the highest quantities of ivermectin were used in BMA 4 (55% of the NL total) in 2016 and in BMA 3 (82%) in 2017.

Praziquantel was used at six farms (40 kg) in 2016 and at seven farms (44 kg) in 2017 (Fig. 6). This drug was used in BMAs 1, 2, and 4 in 2016 and only in BMA 3 in 2017 (Fig. 10b). Praziquantel was not used in any other province in 2016 and 2017, and was not used at any marine fish farms in Canada in 2018. All farms using praziquantel in 2016 and 2017 also treated with ivermectin, but only one farm in 2016 and two in 2017 treated with both praziquantel and emamectin benzoate.

The number of NL farms that used more than one pest control drug in the same year was: six in 2016, nine in 2017, and one in 2018. A small number of NL farms used both emamectin benzoate and ivermectin (both for sea louse control) in the same year: two farms in 2016, three farms in 2017, and one farm in 2018.

Lufeneron was not used in NL in 2016; but was used at one freshwater hatchery in 2017 (1.3 kg) and two hatcheries in 2018 (20.2 kg) (Fig. 6).

6.8.3. Pesticides (NL BMAs)

Pesticides were used at 13 NL farms in 2016; 20 farms in 2017; and 10 farms in 2018 (Table 5). Both azamethiphos and hydrogen peroxide were used in NL (Table 5).

Azamethiphos was used at 13 NL farms (177 kg) in 2016; 20 farms (381 kg) in 2017; and 10 farms (395 kg) in 2018 (Fig. 7). NL accounted for 31% of the number of Canadian farms treated with azamethiphos and 21% of the quantity used in Canada in 2016; 50% of the number of

farms treated and 55% of the quantity used in 2017; and 50% of the number of farms treated and 79% of the quantity used in 2018. Azamethiphos was used in all BMAs except 4, 7, and the inner Bay d'Espoir in 2016, with the highest quantity in BMA 5 (41% of the NL total); in all BMAs except 9 and the inner Bay d'Espoir in 2017 (20-23% in each of BMAs 1, 3, 4, and 8); and only in BMAs 2, 3, and 7 in 2018 (98% in BMA 3) (Fig. 10c).

Hydrogen peroxide was not used in NL in 2016; it was used at four farms (62 413 kg) in 2017; and four farms (30 027 kg) in 2018 (Fig. 7). NL accounted for 13% of the number of Canadian farms treated with hydrogen peroxide and 14% of the quantity used in Canada in 2017; and 11% of the number of farms treated and 9% of the quantity used in 2018. It was used in BMAs 8 (81% of the NL quantity) and 3 (19%) in 2017, and only in BMA 3 in 2018 (Fig. 10c).

In 2017 and 2018, four farms in each year used both azamethiphos and hydrogen peroxide.

7. DRUG AND PESTICIDE USE BY YEAR-CLASS

Marine Atlantic salmon farms in Canada are single-year-class operations, with fallowing between successive year-classes (with very few exceptions). The number and biomass of fish on a farm change over the growout cycle: the weight per fish and total biomass increase over time due to growth, but there will be a decrease in the total number of fish over time due to mortalities; the number and biomass of fish will decrease to zero at harvest.

For the year-class analyses, salmon were categorized as either smolts or pre-markets. Smolts were defined as salmon that had been in seawater (i.e., at marine farms) for ≤12 months (since being transferred from freshwater hatcheries), while pre-markets were salmon that had been in seawater (at marine farms) >12 months. Pre-markets can be subdivided into 'year 2' fish that have been in seawater for 13-24 months and 'year 3' fish that have been in seawater for >24 months. The year-classes present on each farm in each month were estimated based on information provided by K. Sandberg (DFO, Campbell River, BC), G. Cline and R. MacDougall (DFO, St George, NB), and C. Hendry (DFO, St John's, NL). Exact times of transfers from hatcheries to marine sites were often not known, hence the estimated times for the transition from smolt to pre-market are approximate. Year-class information was not obtained for NS farms.

7.1. BRITISH COLUMBIA (BC)

At most marine salmon farms in BC, salmon are grown from smolts (that have been transferred from freshwater hatcheries) to harvest at the same marine site, typically in 20-24 months (DFO 2016a). However, a few marine sites are used as smolt-entry farms, where smolts are received from hatcheries, grown for a few months, and then transferred to other marine farms for growout to harvest. During 2016-2018, no BC farms held 'year 3' Atlantic salmon pre-markets. Very little usage was reported for any of the drugs or pesticides at farms classified as 'other' (holding Atlantic salmon broodstock or growing other species).

For the antibiotic oxytetracycline, the number of treated farms was similar for smolts and pre-markets in 2016 and 2018, while in 2017 only smolts were treated; the quantity used was higher for smolts in all three years (Fig. 11a). Usage of florfenicol was predominantly at farms holding smolts in all three years (Fig. 11a); in BC, this drug is predominantly used to treat yellow mouth disease (caused by the bacterium *Tenacibaculum maritimum*), during the first 3-4 months at sea (P. Whittaker, Grieg Seafood, Campbell River, BC, pers. comm.).

The pest control drug emamectin benzoate was used on both smolts and pre-markets (year 2), but at more farms and higher quantities on pre-markets in all three years (Fig. 11b). The

pesticide hydrogen peroxide was used on smolts and pre-markets in all three years, with higher quantities used on pre-markets in 2016 and 2017, but on smolts in 2018 (Fig. 11b).

7.2. NEW BRUNSWICK (NB)

In NB, all salmon farms in the same BMA must stock in the same year, at 3-yr intervals (with a few exceptions), with mandatory fallowing between successive year-classes. Atlantic salmon are usually grown from smolt (that have been transferred from freshwater hatcheries) to harvest at the same marine site, in 20-30 months, averaging about 25 months (Chang et al. 2014).

Atlantic salmon present at NB farms during 2016 included smolts stocked in 2016 (BMAs 2a and 2b) and 'year 2' pre-markets stocked in 2015 (BMA 1); some farms also had 'year 3' pre-markets that had been stocked in 2014 (BMAs 3a and 3b) until they were harvested during 2016. Salmon present at NB farms during 2017 included smolts stocked in 2017 (BMAs 3a, 3b, and 3c) and 'year 2' pre-markets stocked in 2016 (BMAs 2a and 2b); some farms also had 'year 3' pre-markets that had been stocked in 2015 (BMA 1) until they were harvested during 2017. Salmon present at NB farms during 2018 included smolts stocked in 2018 (BMA 1, plus one farm in BMA 3b) and 'year 2' pre-markets stocked in 2017 (BMAs 3a, 3b, and 3c); some farms also had 'year 3' pre-markets that had been stocked in 2016 (BMAs 2a and 2b) until they were harvested during 2018.

Usage of the antibiotic drug oxytetracycline showed no consistent trend among years (Fig. 12a): in 2016 it was only used on smolts (10 farms); in 2017 the highest quantity was used on 'year 2' pre-markets (two farms), but was also used on smolts (three farms) and 'year 3' pre-markets (one farm); in 2018 it was mostly used on 'year 2' pre-markets, but also on smolts. The use of florfenicol also showed no consistent trend (Fig. 12a): in 2016 it was only used on smolts (seven farms); in 2017 it was mostly used on smolts (11 farms), with a small quantity (3% of the NB total) at one farm holding 'year 2' pre-markets; in 2018 the highest quantity used was on 'year 2' pre-markets (72% of the NB total quantity; all at one farm), with some use on smolts (28% of the NB total quantity; at seven farms).

For the pest control drug emamectin benzoate the number of farms treated was similar for smolts and 'year 2' pre-markets in 2016 and 2017 and higher for smolts in 2018; in 2017 one farm holding 'year 3' pre-markets also treated (Fig. 12b). In all three years the highest quantity of emamectin benzoate was used on 'year 2' pre-markets. Ivermectin was predominantly used on smolts in 2016 and 2018, and only used on smolts in 2017 (Fig 12b); this was related to the long withdrawal period for this drug, which means that it is usually only used on smolts (Roth 2000). Trials using selamectin were at one farm holding older smolts in 2017 and one farm holding 'year 2' pre-markets in 2018.

The pesticide azamethiphos was used predominantly on 'year 2' pre-markets in all three years; in 2016 and 2017 there were smaller numbers of treated farms and quantities used for smolts and 'year 3' pre-markets, while in 2018 only 'year 2' pre-markets were treated (Fig. 12c). Hydrogen peroxide was used on smolts and 'year 2' pre-markets in all three years, with a higher number of treated farms holding smolts in 2016 and 2018, but a higher quantity used at farms holding 'year 2' pre-markets in 2016 and 2017 (Fig. 12c).

7.3. NEWFOUNDLAND & LABRADOR (NL)

In NL, all salmon farms in the same BMA must stock in the same year, at 3-yr intervals (with a few exceptions), with mandatory fallowing between successive year-classes. Atlantic salmon are usually grown from smolt to harvest at the same site, with an average marine growout time of about 24 months (Hamoutene 2014).

Salmon present at NL farms during 2016 included smolts stocked in 2016 (BMAs 1, 4, and 8) and 'year 2' pre-markets stocked in 2015 (BMAs 2, 5, and 9); some farms also had 'year 3' pre-markets that had been stocked in 2014 (BMAs 3 and 7) until they were harvested during 2016. Salmon present at NL farms during 2017 included smolts stocked in 2017 (BMAs 3 and 7) and 'year 2' pre-markets stocked in 2016 (1, 4, and 8); some farms also had 'year 3' pre-markets that had been stocked in 2015 (BMAs 2, 5, and 9) until they were harvested during 2017. Salmon present at NL farms during 2018 included smolts stocked in 2018 (BMAs 2, 5, and 9, plus one farm in BMA 3) and 'year 2' pre-markets stocked in 2017 (BMAs 3, and 7); one farm also had 'year 3' pre-markets that had been stocked in 2016 (BMA 8) until they were harvested during 2018.

The antibiotic drug oxytetracycline was only used on 'year 2' pre-markets in 2016; mostly used on 'year 2' pre-markets, but also on smolts, in 2017; and not used in NL in 2018 (Fig. 13a). Florfenicol was only used on smolts in all three years (Fig. 13a).

The pest control drug emamectin benzoate was predominantly used on 'year 2' pre-markets in all three years; it was also used on smolts in all three years, and at one farm holding 'year 3' pre-markets in 2016 (Fig. 13b). Ivermectin was only used on smolts in all three years, although there was very little usage in 2018 (Fig 13b); as mentioned above, the long withdrawal period for this drug means that is usually only used on smolts (Roth 2000). Praziquantel was only used in 2016 and 2017 and only on smolts, except for one farm holding 'year 2' pre-markets in 2016 (Fig. 13b).

The pesticide azamethiphos was used mostly on 'year 2' pre-markets in all three years; it was also used on smolts in all three years, and on 'year 3' pre-markets in 2016 and 2017 (Fig. 13c). Hydrogen peroxide was not used in 2016. In 2017 and 2018, it was used at similar numbers of farms in both years, but with higher quantities used for 'year 2' pre-markets; it was not used on 'year 3' pre-markets in any year (Fig. 13 c).

8. MONTHLY TRENDS IN DRUG AND PESTICIDE USE

Histograms of the number of farms treating with any drugs or pesticides, by month in 2016-2018, are shown in Fig. 14. In BC, drugs and pesticides were used in all 12 months in 2016 and 2017, and in all months except January in 2018. In NB and NL, there was little use of these chemicals in the winter (especially February-April in NB, and January-May in NL). In NS, only antibiotics were used in 2016 (August) and 2018 (June-August), and no drugs and pesticides were used in 2017.

At individual farms, drugs and pesticides were usually used during fewer than six months of the year: in BC, means 2.2-3.1 months, maxima 5-8 months; in NB, means 3.3-5.5 months, maxima 7-10 months; in NS, means 1.0-1.3 months, maxima 1-2 months (except no usage reported in 2017); in NL, means 3.6-5.4 months, maxima 6-7 months (Table 9).

8.1. ANTIBIOTIC DRUGS

Oxytetracycline was used in BC in 7-9 months per yr during 2016-2018; there were no treatments in January in any of the three years (Fig. 15a). The maximum number of farms treated per month in BC was in July in 2016 (n=3); in August, September, and October in 2017 (n=2), and in September in 2018 (n=4); the maximum quantity used per month in BC was in September in all three years. Oxytetracycline was used in NB in 3-6 months per yr; there were no treatments in February-April and October-November in any of the three years (Fig. 15a). The maximum number of farms treated per month in NB was in May in 2016 (n=4); in June in 2017 (n=3); and in July and September in 2018 (n=2). The maximum quantity used per month in NB

was in May in 2016; in June in 2017; and in September in 2018. Oxytetracycline was used in NS only in August 2016 and June-July 2018. Oxytetracycline was used in NL in 4-5 months per yr in 2016 and 2017, but was not used in 2018; there were no treatments in January-April, August, and October in any year (Fig. 15a). The maximum number of farms treated per month in NL was in November in 2016 (n=2) and in June in 2017 (n=3); the maximum quantities used were in these same months. At the individual farm level, the number of months per year when oxytetracycline treatments occurred averaged 1.0-2.1, with maxima of 1-6 months (Table 9).

Florfenicol was used in BC in all 12 months in all three years (Fig. 15b). The maximum number of farms treated per month in BC was in May in 2016 (n=13); in January and February in 2017 (n=9); and in May in 2018 (n=12). The maximum quantity used per month in BC was in May in 2016; in January in 2017; and in May in 2018. Florfenicol was used in NB in 4-6 months per yr; there were no treatments in March-April and August-September in any of the three years (Fig. 15b). The maximum number of farms treated per month in NB was in May in 2016 (n=3), in June in 2017 (n=8), and in May and July in 2018 (n=3). The maximum quantity used per month in NB was in December in 2016; in January in 2017; and in July in 2018. Florfenicol was used in NS only in August 2018 (one farm). Florfenicol was used in NL in 3-5 months per yr; there were no treatments in February-May in any of the three years (Fig. 15b). The maximum number of farms treated per month in NL was in June in 2016 (n=3); in August and October in 2017 (n=2); and in June in 2018 (n=3). The maximum quantity used per month in NL was in November in 2016; in August in 2017; and in June in 2018. At the individual farm level, the number of months per year when florfenicol treatments occurred averaged 1.0-3.0, with maxima of 1-6 months (Table 9).

Erythromycin was used in BC only in October 2018, at one farm. In NB, erythromycin was used only in May 2016, at one farm. Erythromycin was not used in NS. In NL, erythromycin was used only in June 2016, at one farm.

Ormetoprim was used in BC in June-July and October-December in 2016 (maximum one farm per month) and in June-October 2018 (maximum one farm per month). The maximum monthly usage was in June in both 2016 and 2018. Ormetoprim was not used in BC in 2017 and was not used in NB, NS, and NL in any of the three years.

Trimethoprim was not used in BC and NS in 2016-2018. In NB, it was used in June-August in 2016 (maximum two farms, in August); in June and October in 2017 (one farm each month); and in July 2018 (one farm). In NL, trimethoprim was used only in September 2016 (two farms).

8.2. PEST CONTROL DRUGS

Emamectin benzoate was used in BC in 10 months in each year; however, the two months without treatments were not the same in each year (Fig. 15c). The maximum number of farms treated per month in BC was in February in 2016 (n=9); in January and February in 2017 (n=8); and in February and August in 2018 (n=8). The maximum quantity used per month in BC was in February in 2016; in November in 2017; and in February in 2018. Emamectin benzoate was used in NB in 8-9 months per yr; there were no treatments in February-April in any of the three years (Fig. 15c). The maximum number of farms treated per month in NB was in August, September, and November in 2016 (n=12); in August in 2017 (n=8); and in November in 2018 (n=10). The maximum quantity used per month in NB was in September in 2016 and 2017; and in November in 2018. Emamectin benzoate was not used in NS during 2016-2018. Emamectin benzoate was used in NL in 5-7 months per yr; there were no treatments in January-May in any of the three years (Fig. 15c). The maximum number of farms treated per month in NL was in August in 2016 (n=11); in July in 2017 (n=10); and in September in 2018 (n=10). The maximum quantity used per month in NL was in September in 2016; in July in 2017; and in July in 2018. At

the individual farm level, the number of months per year when emamectin benzoate treatments occurred averaged 1.1-4.6, with maxima of 2-8 months (Table 9).

Ivermectin was not used in BC and NS during 2016-2018. Ivermectin was used in NB in 5-7 months per yr; there were no treatments in January-April in any of the three years (Fig. 15d). The maximum number of farms treated per month in NB was in July, September, October, and November in 2016 (n=10); in September, October, and November in 2017 (n=10); and in September and October in 2018 (n=11). The maximum quantity used per month in NB was in October in all three years. Ivermectin was used in NL in 2-6 months per yr; there were no treatments in January-May in any of the three years (Fig. 15d). The maximum number of farms treated per month in NL was in June, July, August, and September in 2016 (n=6); in July, August, September, and October in 2017 (n=9); and in July and August in 2018 (n=1). The maximum quantity used per month in NL was in September in 2016; in October in 2017; and in July in 2018. At the individual farm level, the number of months per year when ivermectin treatments occurred averaged 2.0-5.6, with maxima of 2-7 months (Table 9).

Selamectin was used only in two one-week trials: at one NB farm in October 2017 and at a different NB farm in July 2018.

Praziquantel was used only in NL and only in November 2016 and November 2017.

8.3. PESTICIDES

Azamethiphos was not used in BC and NS during 2016-2018. Azamethiphos was used in NB in 5-9 months per yr; there were no treatments in February-April in any of the three years (Fig. 15e). The maximum number of farms treated per month in NB was in October in 2016 (n=17); in October in 2017 (n=10); and October and November in 2018 (n=5). The maximum quantity used per month in NB was in September in 2016; in October in 2017; and in November in 2018. Azamethiphos was used in NL in 5-6 months per yr; there were no treatments in January-June in any of the three years (Fig. 15e). The maximum number of farms treated per month in NL was in September in 2016 (n=9); in November in 2017 (n=15); and in September in 2018 (n=9). The maximum quantity used per month in NL was in August in 2016; in November in 2017; and in September in 2018. At the individual farm level, the number of months per year when azamethiphos treatments occurred averaged 1.5-3.5, with maxima of 3-8 months (Table 9).

Hydrogen peroxide was used in BC in 10-11 months per yr (Fig. 15f). The maximum number of farms treated per month in BC was in February, March, September, October, and December in 2016 (n=2); in April, May, July, and October in 2017 (n=3); and in March and June in 2018 (n=5). The maximum quantity used per month in BC was in March in 2016; in April in 2017; and in November in 2018. Hydrogen peroxide was used in NB in 4-6 months per yr; there were no treatments in February, March, and September in any of the three years (Fig. 15f). The maximum number of farms treated per month in NB was in May in 2016 (n=7); in May in 2017 (n=4); and in November in 2018 (n=8). The maximum quantity used per month in NB was in May in 2016 and 2017; and in November in 2018. Hydrogen peroxide was not used in NS during 2016-2018. Hydrogen peroxide was not used in NL in 2016, and was used in four months in 2017 and two months in 2018; there were no treatments in January-May and August-September in any year (Fig. 15f). The maximum number of farms treated per month in NL was in June in 2017 (n=2) and in June and October in 2018 (n=2). The maximum quantity used per month in NL was in June in both 2017 and 2018. At the individual farm level, the number of months per year when hydrogen peroxide treatments occurred averaged 1.0-1.6, with maxima of 1-3 months (Table 9).

9. INTER-ANNUAL TRENDS IN DRUG AND PESTICIDE USE

Data on the use of individual chemicals in each year have been presented in the previous sections. Following is a summary of between-year trends for the most commonly used drugs and pesticides during 2016-2018. Because data are reported on a calendar year basis, we also use the calendar year in our analyses. It should be noted, however, that chemical use at farms changes over the production cycle (usually about 18-29 months for salmon), as well as during the annual seasonal cycle. The chemical use at a farm in a given calendar year will therefore depend on the life stage present (chemical use at farms holding smolts will likely be less than at farms holding pre-markets, due to the differences in biomass, although this is not the case for all chemicals) and the number of months that the fish are present during the year (which depends on stocking and harvest dates).

9.1. CANADA

During 2016-2018, the number of Canadian marine finfish farms in the NAPRD increased from 152 in 2016 to 162 in 2017, but then decreased to 136 in 2018 (Table 5), while the production of marine salmonids in Canada showed a slight decrease (Table 2, Fig. 16a). The number of Canadian marine finfish farms treated with drugs and pesticides decreased from 128 in 2016, to 120 in 2017, and to 108 in 2018 (Table 5).

The number of Canadian marine finfish farms treated with antibiotic drugs was similar in 2016 and 2017 (67 and 66, respectively) and decreased to 59 in 2018 (Table 5). During these years, the number of farms treated with oxytetracycline and the quantity used decreased (Fig. 16a). The number of farms treated with florfenicol showed little change, while the quantity of florfenicol used increased (Fig. 16a).

The number of Canadian marine finfish farms treated with pest control drugs was similar in 2016 and 2017 (79 and 77, respectively) and decreased to 63 in 2018 (Table 5). Emamectin benzoate and ivermectin both showed decreases in the number of farms treated and the quantity used, especially from 2017 to 2018 (Fig. 16a).

The number of Canadian marine finfish farms treated with pesticides increased from 54 in 2016 to 59 in 2017, then decreased to 53 in 2018 (Table 5). In the same years, azamethiphos showed decreasing trends in the number of farms treated and the quantity used, while hydrogen peroxide showed an increasing trend in the number of farms treated, but a decreasing trend in the quantity used (fig. 16a).

9.2. BRITISH COLUMBIA (BC)

During 2016-2018, the number of BC farms in the NAPRD increased from 78 in 2016 to 81 in 2017, then decreased to 73 in 2018 (Table 5). During this time the production of marine salmonids in BC remained fairly constant (Table 2, Fig. 16b). The number of BC marine finfish farms treated with drugs and pesticides was 67 in 2016 and 2017, and 63 in 2018 (Table 5).

The number of BC marine finfish farms treated with antibiotic drugs was similar in all three years (41 in 2016, 40 in 2017 and 2018) (Table 5). In the same years, oxytetracycline showed an increase in the number of farms treated and the quantity used, especially from 2017 to 2018 (Fig. 16b); while florfenicol showed little change in the number of farms treated, but an increase in the quantity used (Fig. 16b).

The number of BC marine finfish farms treated with pest control drugs increased from 35 in 2016 to 38 in 2017, then decreased to 32 in 2018 (Table 5). In the same years, emamectin benzoate (the only pest control drug used in BC) showed an increase in the number of farms

treated and the quantity used from 2016 to 2017, but decreases in both parameters from 2017 to 2018 (Fig. 16b).

The number of BC marine finfish farms treated with pesticides increased from 11 in 2016, to 17 in 2017, and to 22 in 2018 (Table 5). In the same years, number of farms treated with hydrogen peroxide (the only pesticide used in BC) and the quantity used both increased (Fig. 16b).

9.3. NEW BRUNSWICK (NB)

During 2016-2018, the number of NB farms in the NAPRD increased from 44 in 2016 to 45 in 2017, then decreased to 36 in 2018 (Table 5). During this time the production of marine salmonids in NB decreased slightly from 2016 to 2017, then increased from 2017 to 2018 (Table 2, Fig. 16c). The number of NB marine finfish farms treated with drugs and pesticides decreased from 38 in 2016, to 31 in 2017, to 28 in 2018 (Table 5).

The number of NB marine finfish farms treated with antibiotic drugs increased from 14 in 2016 to 17 in 2017, then decreased to 12 in 2018 (Table 5). In the same years, the number of farms treated with oxytetracycline decreased, while the quantity used showed little change (Fig. 16c). For florfenicol, the number of farms treated increased from 2016 to 2017, then decreased from 2017 to 2018, while the quantity used showed an overall increase (Fig. 16c).

The number of NB marine finfish farms treated with pest control drugs decreased from 26 in 2016 to 20 in 2017 and 2018 (Table 5). In the same years, the number of farms treated with emamectin benzoate and the quantity used decreased, while for ivermectin, the number of farms treated did not change, but the quantity used decreased (Fig. 16c).

The number of NB marine finfish farms treated with pesticides decreased from 30 in 2016 to 22 in 2017 and 21 in 2018 (Table 5). The number of farms treated with azamethiphos was similar in 2016 and 2017, but showed a large decrease in 2018, while the quantity used showed a large decrease during these years (Fig. 16c). For hydrogen peroxide, the number of farms treated and the quantity used showed large decreases from 2016 to 2017, but small increases from 2017 to 2018 (Fig. 16c).

9.4. NOVA SCOTIA (NS)

During 2016-2018, the number of NS farms in the NAPRD was eight in 2016 and 2018, and 11 in 2017 (Table 5). During this time the production of marine salmonids in NS increased from 2016 to 2017, then decreased from 2017 to 2018 (Table 2, Fig. 16d).

The number of NS marine finfish farms treated with drugs and pesticides decreased from two in 2016 to none in 2017, then increased to three in 2018 (Table 5). Oxytetracycline was used in NS in 2016 and 2018, with the highest quantity in 2016 (Fig. 16d). Florfenicol was used only in 2018 (Fig. 16d). No antibiotics, and no other drugs and pesticides, were used in NS in 2017.

9.5. NEWFOUNDLAND & LABRADOR (NL)

During 2016-2018, the number of NL farms in the NAPRD increased from 22 in 2016 to 25 in 2017, then decreased to 19 in 2018 (Table 5). During this time the production of marine salmonids in NL decreased (Table 2, Fig. 16e). The number of NL marine finfish farms treated with drugs and pesticides was similar in 2016 and 2017 (21 and 22, respectively) then decreased to 14 in 2018 (Table 5).

The number of NL marine finfish farms treated with antibiotic drugs was similar in 2016 and 2017 (ten and nine, respectively), then decreased to four in 2018 (Table 5). There was a small increase in the number of farms treated with oxytetracycline from 2016 to 2017, while there was

a small decrease in the quantity used; there was no use of oxytetracycline in NL in 2018 (Fig. 16e). There was a small decrease in the number of farms treated with florfenicol during 2016-2018, while the quantity used showed a large decrease from 2016 to 2017, then a small increase from 2017 to 2018 (Fig. 16e).

The number of NL marine finfish farms treated with pest control drugs was similar in 2016 and 2017 (18 and 19, respectively) then decreased to 11 in 2018 (Table 5). In the same years, the number of farms treated with emamectin benzoate decreased, while the quantity used increased from 2016 to 2017, then decreased from 2017 to 2018 (Fig. 16e). For ivermectin, the number of farms treated and the quantity used both showed small increases from 2016 to 2017, then large decreases from 2017 to 2018 (Fig. 16e). For praziquantel, there were small increases in the number of farms treated and the quantity used from 2016 to 2017, then it was not used in 2018 (Fig. 16e).

The number of NL marine finfish farms treated with pesticides increased from 13 in 2016 to 20 in 2017, then decreased to 10 in 2018 (Table 5). The number of farms treated with azamethiphos increased from 2016 to 2017, then decreased from 2017 to 2018, while the quantity used showed an overall increase during 2016-2018 (Fig. 16e). Hydrogen peroxide was not used in NL in 2016; from 2017 to 2018, the number of farms treated was constant, while the quantity used decreased (Fig. 16e).

10. SUMMARY AND CONCLUSIONS

1. The information summarized in this report came from the National Aquaculture Public Reporting Data (NAPRD) website, which used data from the Aquaculture Integrated Information System (AQUIIS). This report focusses on drugs and pesticides used for disease and pest control at marine finfish farms in Canada.
2. The design of a post-deposit monitoring program for drugs and pesticides used in marine finfish aquaculture requires data on the locations of treated farms, the quantities used, and the timing of treatments. For drugs and pesticides used at marine farms, these data are available at the farm level (but not for individual net-pens) from NAPRD and AQUIIS.
3. The dataset records indicate that the aquaculture industry has submitted at least one record pertaining to the use of 11 drugs and pesticides at marine finfish farms. The active ingredients include the following:
    a. Antibiotic drugs: oxytetracycline, florfenicol, erythromycin, ormetoprim, trimethoprim
    b. Pest control drugs: emamectin benzoate, ivermectin, selamectin, praziquantel
    c. Pesticides: azamethiphos, hydrogen peroxide
4. One other drug, lufeneron, is used for sea louse control in freshwater hatcheries, but may be deposited in marine waters after treated smolts have been transferred to marine farms. For this drug, data are available on which hatcheries were treated and the quantities used, but the locations of marine farms that received treated smolts were not available in NAPRD and AQUIIS.
5. Drugs and pesticides are applied at finfish farms using two treatment types:
    a. In-feed treatment: for antibiotics and pest control drugs
    b. Bath treatment: for pesticides, using either tarps or wellboats
6. This data set is relatively new and is suffering from the growing pains associated with most new databases. In the case of the present data we have discovered some inconsistencies in

how the data has been reported and recorded in the foundation data sets, and we have tried to account for these inconsistencies in our analyses.

   a. the definition of a “treatment” is somewhat vague and was used differently among farms, provinces, and years. From a monitoring perspective, the definition of a treatment is important; i.e., we need to know the specific times and locations of chemical releases into the environment. However, this did not affect our analyses of quantities of drugs and pesticides used per farm per year.
   b. NAPRD tables have incorrect values for hydrogen peroxide usage in BC in 2016.
   c. NAPRD tables do not include data on praziquantel use in NL in 2016.
   d. NAPRD tables do not include data on selamectin trials in NB in 2017 and 2018.

7. The three years of available data and the evolving quality control of the dataset mean that the dataset is insufficient to draw any solid conclusions on the patterns of use. However, the preliminary suggestions derived from the dataset include:
   a. There are differences in chemical usage among regions/provinces.
   b. There are differences in chemical usage among years.
   c. The treatment frequency data are of insufficient quality to warrant analyses, because there is no consistent definition of treatment.
8. Half of the farms in the database in the three years were in BC (50-54%), followed by NB (26-29%), NL (14-15%), and NS (5-7%). These differences influence the relative numbers of farms treated and chemicals used per province; e.g., the number of farms treated and quantity used were highest in BC for many chemicals, but this largely reflects the larger number of farms in that province.
9. Drugs and pesticides were used in all provinces where marine finfish farming occurs:
   a. Individual farms reported using from zero to six of these chemicals in 2016, and zero to five in 2017 and 2018.
   b. The most common number of these chemicals used per farm in Canada was one (in all three years).
   c. Farms reporting the largest number of these chemicals used per farm were in NB in 2016 (six chemicals); in NB and NL in 2017 (five chemicals), and in NL in 2018 (five chemicals).
   d. The province with the lowest number of these chemicals used per farm was NS in all three years (maximum of one drug or pesticide per farm in 2016 and 2018, and none in 2017).
   e. The maximum number of sea louse control chemicals (including pest control drugs and pesticides) used per farm per yr was four in NB and NL, two in BC, and none in NS.
10. Differences in drug and pesticide usage among provinces:
   a. When all drugs and pesticides are considered:
      i. The number of Canadian farms treated with at least one drug or pesticide was 108-128 per yr (74-84% of Canadian farms in the NAPRD).
      ii. The largest number of farms treated was in BC in all three years (63-67 farms per yr; 52-58% of Canadian treated farms); BC also had the largest number

of active farms in these years (73-81 farms per yr; 50-54% of Canadian farms in the NAPRD).

b. When antibiotic drugs are considered:

    i. The number of Canadian farms treated with antibiotics was 59-67 per yr (41-44% of Canadian farms in the NAPRD).
    ii. The largest number of farms treated with antibiotics was in BC in all three years (40-41 farms per yr; 61-68% of treated Canadian farms).
    iii. Among the antibiotics, florfenicol was used at the most farms (47-50 Canadian farms per yr). The highest usage among provinces was in BC: 34-35 farms per yr (70-74% of the number of Canadian farms treated); 90-93% of the quantity used in Canada.
    iv. Oxytetracycline was the next most used antibiotic drug (at 17-24 Canadian farms per yr). The largest number of farms treated was in NB in 2016 (10 farms; 42% of treated Canadian farms), in BC in 2017 (7 farms; 41%), and in BC in 2018 (10 farms; 59%). The largest quantity used was in NL in 2016 and 2017 (50-52% of the Canadian total) and in BC in 2018 (66%).
    v. Only a few farms used both oxytetracycline and florfenicol in the same year (2-6 farms per yr).
    vi. Three other antibiotic drugs were used: erythromycin (0-2 farms per yr); ormetoprim (0-3 farms per yr); and trimethoprim (1-5 farms per yr).

c. When pest control drugs are considered:

    i. The number of Canadian farms treated with pest control drugs was 63-79 per yr (46-52% of Canadian farms in the NAPRD).
    ii. The largest number of farms treated with pest control drugs was in BC in all three years (32-38 farms per yr; 44-51% of treated Canadian farms). No pest control drugs were used in NS.
    iii. Among the pest control drugs, emamectin benzoate (for sea louse control) was used at the most farms (56-70 Canadian farms per yr). The largest number of farms treated with emamectin benzoate was in BC (32-38 farms per yr; 21-29% of the Canadian total), but the largest quantity used was in NL in each year (44-57% of Canadian total).
    iv. Ivermectin (for sea louse control) was only used in NB and NL. The largest number of farms treated with ivermectin was in NB in each year: 14 farms (70% of Canadian total) in 2016; 13 farms (59%) in 2017; 13 farms (93%) in 2018. The largest quantity used was also in NB in each year: 64% of Canadian total in 2016; 52% in 2017: and >99% in 2018.
    v. Several farms used both emamectin benzoate and ivermectin in the same year (7-11 farms per yr).
    vi. Selamectin (for sea louse control; structurally related to ivermectin) was used on a trial basis in NB in 2017 and 2018; a one-week trial at one farm in October 2017, and another one-week trial at a different farm in July 2018; in both cases, the farms using selamectin did not use any other pest control drug in the same year.
    vii. Praziquantel (for worm control) was used only in NL in 2016 and 2017, and was not used in any province in 2018.

d. When pesticides are considered:

i. The number of Canadian farms treated with pesticides was 53-59 per yr (36-39% of Canadian farms in the NAPRD). Only two pesticides were available for use: azamethiphos and hydrogen peroxide.
ii. Azamethiphos was used at 20-42 Canadian farms per yr. It was only used in NB and NL. The largest number of farms treated was in NB in 2016 (29 farms; 69% of the Canadian total), and there were equal numbers of treated farms in NB and NL in 2017 (20 farms each) and 2018 (10 farms each). The largest quantity used was in NB in 2016 (79% of the Canadian total), in NL in 2017 (55%), and in NL in 2018 (79%).
iii. Hydrogen peroxide was used at 25-37 Canadian farms per yr. It was not used in NL in 2016 and not used in NS in any of the three years. The largest number of farms treated and the largest quantity used were in NB in 2016 (14 farms, 56% of farms treated; 63% of quantity used); in BC in 2017 (17 farms, 57% of farms treated; 63% of quantity used); and in BC in 2018 (22 farms, 59% of farms treated; 61% of quantity used).
iv. Several farms used both azamethiphos and hydrogen peroxide in the same year (4-13 farms per yr).

11. Differences in the use of different treatment types among provinces:

a. Both in-feed and bath treatments were used in all provinces except NS in all three years; in NS, only in-feed treatments were used in 2016 and 2018, and there were no treatments using either type in 2017.

b. In BC, 78-82% of reporting farms in each year used at least one in-feed treatment; 14-30% used at least one bath treatment; and 10-22% used at least one of each treatment type.

c. In NB, 48-64% of reporting farms in each year used at least one in-feed treatment; 49-68% used at least one bath treatment; and 31-44% used at least one of each treatment type.

d. In NS, 25% of reporting farms in 2016 used at least one in-feed treatment and none used bath treatments; in 2017, neither in-feed nor bath treatments were used at any farm; in 2018, 38% used at least one in-feed treatment and none used bath treatments.

e. In NL, 64-86% of reporting farms in each year used at least one in-feed treatment; 53-80% used at least one bath treatment; and 47-72% used at least one of each treatment type.

12. Differences in drug and pesticide usage between year-classes:

a. Antibiotic drugs

i. Oxytetracycline: there were no consistent differences in the use of this drug by different year-classes.
ii. Florfenicol: this drug was used mostly for smolts in all provinces and years. The only exception was in NB in 2018, where there was more quantity used in ‘year 2’ pre-markets (due to high usage at one farm).

b. Pest control drugs

i. Emamectin benzoate: the quantity used was higher in ‘year 2’ pre-markets than in smolts in all provinces and years. However, the number of farms treated was not always higher in the ‘year 2’ fish; hence the higher quantity for ‘year 2’ fish was at least partly due to the higher biomass in that year-class.

ii. Ivermectin: was only used in NB and NL, was used predominantly on smolts.
iii. Selamectin: was only used in NB on a trial basis. The trial in 2017 was at a farm holding smolts, while the trial in 2018 was at a farm holding 'year 2' pre-markets.
iv. Praziquantel: was only used in NL and only in 2016 and 2017. The treated fish were predominantly smolts in 2016 and entirely smolts in 2017.

c. Pesticides

i. Azamethiphos: in NB, the number of treated farms and the quantity used were both higher for 'year 2' pre-markets in all years (in 2018, this pesticide was not used on smolts). In NL, the number of treated farms and the quantity used were both higher for 'year 2' pre-markets in 2016 and 2018; in 2017, the quantity used was higher in 'year 2' fish, while the number farms treated was the same for smolts and 'year 2' fish.
ii. Hydrogen peroxide: there were no consistent differences in the use of this pesticide by different year-classes.

13. Differences in the intra-annual (monthly) timing of treatments among provinces:

a. In BC, treatments occurred in all months of the year. Sea louse treatment timing is related to DFO sea louse management requirements and the timing of wild salmon migrations.

b. In NB and NL, treatments did not occur in the winter and early spring.

c. In NS, the only treatments were in June-August (antibiotics only).

14. Differences in drug and pesticide usage among years:

a. The three years of available data are insufficient to determine clear trends.

b. In Canada, there were small decreases in the number of treated farms and the quantity used for most of the commonly used drugs and pesticides; however there was increase in the number of farms treating with hydrogen peroxide and an increase in the quantity of florfenicol used.

c. In BC, the number of farms treated and quantity used showed increasing trends for oxytetracycline and hydrogen peroxide. For florfenicol, the number of farms treated showed little change, while the quantity used increased. For emamectin benzoate, there were no clear trends in usage.

d. In NB, there were decreasing trends in the number of farms treated and quantity used for most of the most commonly used chemicals. Florfenicol showed a trend of increasing usage, especially in quantity used. Ivermectin showed no change in the number of farms treated, but a decrease in the quantity used.

e. In NS, only antibiotics were used, and only 0-3 farms were treated per yr (there was no usage of any drugs or pesticides in NS in 2017).

f. In NL, there were decreasing trends in the usage of antibiotics and pest control drugs, but increasing trends in the usage of pesticides.

15. The quantity used of a drug or pesticide is not indicative of the environmental risk, due to differences in toxicity and environmental thresholds among the chemicals. Hydrogen peroxide was by far the most used chemical (by quantity), but the usage of this chemical probably has a low environmental risk. Also, the quantity used is not necessarily indicative

of the quantity impacting the environment, because some of the chemical will be metabolized by the treated fish and/or broken down in the environment.

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TABLES

Table 1. List of drugs and pesticides used at Canadian marine finfish farms, 2016-2018. Ivermectin and azamethiphos are not currently available for use in BC. Selamectin has only been used for trials (in NB in 2017 and 2018). Praziquantel was used only in NL (and only in 2016 and 2017). a.i. = active ingredient. Lufeneron can only be used in freshwater hatcheries. Data source: National Aquaculture Public Reporting Data (NAPRD) (DFO 2018b, 2020b).

Active ingredient	Commercial products	Application method	Recommended dosage and withdrawal period*
Antibiotic drugs (for bacterial pathogen control)			
Oxytetracycline hydrochloride	Terramycin-Aqua©	In-feed	75 mg (a.i.) per kg fish per d for 10 d. Withdrawal period 40 d (≥10°C), 80 d (<10°C).
Florfenicol	Aquaflor®	In-feed	10 mg (a.i.) per kg fish per d for 10 d. Withdrawal period 12 d.
Erythromycin	Erythromycin	In-feed	Extra-label
Ormetoprim & Sulfadimethoxine	Romet® 30	In-feed	50 mg (a.i.) per kg fish per d for 5 d. Withdrawal period 42 d.
Trimethoprim & Sulfadiazine powder	Tribrissen®	In-feed	30 mg (a.i.) per kg fish per d for 7-10 d. Withdrawal period 80 d.
Pest control drugs (for sea louse control; except Praziquantel, for parasitic worm control)			
Emamectin benzoate	Slice®	In-feed	50 μg (a.i.) per kg of fish per d for 7 d. No withdrawal period.
Ivermectin	Ivomec®; Noromectin®	In-feed	Extra-label. 0.02-0.2 mg (a.i.) per kg fish, once or twice weekly, for up to several weeks. Withdrawal period 180 d (Canada). (Davies & Rodger 2000; Roth 2000; Burridge 2003; Bright & Dionne 2005).
Selamectin	–	In-feed	Extra-label
Praziquantel	–	In-feed	Extra-label

* Recommended dosages and withdrawal periods for drugs (excluding extra-label use) are available from the Canadian Food Inspection Agency's Compendium of Medicating Ingredient Brochures (CFIA 2021).

Table 1 (cont'd). List of drugs and pesticides used at Canadian marine finfish farms, 2016-2018.

Active ingredient	Commercial products	Application method	Recommended dosage and withdrawal period**
Pest control drugs (for sea louse control in freshwater hatcheries)			
Lufeneron	Imvixa™	In-feed	Emergency Drug Release (freshwater only). 5 mg (a.i.) per kg fish per d for 7 d. Minimum 7 d post-treatment before transfer to sea. (Based on usage in Chile: McHenery 2016; JECFA 2017).
Pesticides (for sea louse control)			
Azamethiphos	Salmosan® Vet	Bath (tarp or wellboat)	10 g (a.i.) per 100 m^3 (tarp) or per 80-105 m^3 (wellboat) for 30-60 min. Minimum 7 d between treatments. Maximum 10 treatments during life-cycle of fish. Withdrawal period 48 h.
Hydrogen peroxide	Interox® Paramove 50™; Aquaparox 50™	Bath (wellboat)	1200-1800 mg (a.i.) per L for 20 min. Minimum 7 d between treatments. Maximum 5-6 treatments per yr. No withdrawal period.

** Recommended dosages and withdrawal periods for pesticides are available from the Pest Management Regulatory Agency's Search Product Label tool (PMRA 2021).

Table 2. Marine salmonid aquaculture production (t) in Canada, 2016-2018. In BC, Atlantic salmon (Salmo salar) represented 96% of all marine finfish aquaculture production in 2018 (DFO 2019a). In Atlantic Canada, marine finfish aquaculture production was all Atlantic salmon, except for limited production of steelhead (Oncorhynchus mykiss). Data sources: Statistics Canada (2020); NLDFLR (2017, 2018, 2019a).

Province	2016	2017	2018
British Columbia (BC)	90 500	86 700	87 100
New Brunswick (NB)	27 000	23 900	28 300
Nova Scotia (NS)	6 000	11 100	7 900
Newfoundland & Labrador (NL)	25 400	18 800	15 100
Totals	**148 900**	**140 500**	**138 400**

Table 3. Number of Canadian marine finfish aquaculture licences and number of farms in the National Aquaculture Public Reporting Data (NAPRD) for drugs and pesticides, by province, 2016-2018. The New Brunswick numbers include one farm which is not a commercial operation (it is being used to hold small numbers of wild salmon for the Fundy Salmon Recovery Project). The numbers of licenced farms are for 2018 and include both active and inactive farms. Data sources for the number of licensed farms: DFO (2019a), NBDAAF (2020), NLDFLR (2019a), NSDFA (2020). Data source for NAPRD marine finfish data: DFO (2020b).

DFO Jurisdiction and Province	Number of licenced farms (2018)	Number of farms in NAPRD					
		2016	2017	2018	At least 1 year	At least 2 years	All 3 years
Canada (total)	328	152	162	136	180	161	109
DFO Pacific Region							
British Columbia (BC)	116	78	81	73	90	79	63
DFO Maritimes Region							
New Brunswick (NB)	89	44	45	36	47	47	31
Nova Scotia (NS)	35	8	11	8	13	8	6
Maritimes Region subtotal	124	52	56	44	60	55	37
DFO Newfoundland & Labrador Region							
Newfoundland & Labrador (NL)	88	22	25	19	30	27	9

Table 4a. Number of licensed and active Canadian marine finfish farms, per provincial subarea, 2016-2018: BC Fish Health Surveillance Zones (FHSZs; see Fig. 2). The number of active farms is the number of farms reported in the NAPRD marine finfish data. Atlantic salmon was the predominant species farmed. Each FHSZ included salmon farms holding smolts and pre-market fish in each year. A few sites farmed other species, including chinook salmon, steelhead, and sablefish. Data sources: DFO (2016b, 2019a, 2020b).

FHSZ	Area	Number of licensed farms (2018)	Number of active farms		
			2016	2017	2018
2-3	Vancouver Island, west coast, south	24	18	17	12
2-4	Vancouver Island, west coast, north	19	11	14	15
3-1	Sechelt Inlet & Jervis Inlet	10	7	6	6
3-2	Discovery Islands	23	10	11	9
3-3	Broughton Archipelago & Hardwicke I.	21	19	20	19
3-4	Queen Charlotte Strait	13	7	8	9
3-5	Central Coast	6	6	5	2

Table 4b. Number of licensed and active Canadian marine finfish farms, per provincial subarea, 2016-2018: NB Bay Management Areas (BMAs; see Fig. 2). NB farms stocked only Atlantic salmon during these years. Farms in the same BMA stock in the same year, at 3-yr intervals (there were a few exceptions allowed during this period: three farms in BMA 2a stocked in 2014 and one farm in BMA 3b stocked in 2018). The farm in BMA 5 (Dark Harbour, Grand Manan Island) is a non-commercial operation, holding 3000-4000 wild Atlantic salmon for the Fundy Salmon Recovery Project). BMA 6 (Letete Passage) is designated for non-salmonids only, but has been inactive since 2011. Data sources: G. Smith, NBDAAF, St. George, NB; G.H. Cline and R.W. MacDougall (DFO, St George, NB. pers. comm.).

BMA	Area	Number of licensed farms	Year-class	Number of stocked farms
1	Passamaquoddy Bay,	34	2015	16
	Deer I. & Campobello I.	32	2018	14
2a	Letang area	20	2016	7
2b	Grand Manan I. east	12	2016	10
3a	Maces Bay area	12	2014	4
			2017	5
3b	Grand Manan I. south	9	2014	8
		9	2017	6
		8	2018	1
3c	Head Harbour, Campobello I.	2	2017	2
5	Dark Harbour, Grand Manan I.	1	–	1
6	Letete Passage	2	–	0

Table 4c. Number of licensed and active Canadian marine finfish farms, per provincial subarea, 2016-2018: NL Bay Management Areas (BMAs; see Fig. 2). BMAs 1-11 encompass the existing marine Atlantic salmon farms. Farms in the same BMA stock in the same year, at 3-yr intervals (there was one exception during this period: one farm in BMA 3 that stocked in 2018). The BMA system does not include the brackish inner Bay d'Espoir area, which is used for steelhead farming. Data source: C. Hendry (DFO, St John's, NL).

BMA	Area	Number of licensed farms	Year-class	Number of stocked farms
1	Mal Bay	3	2016	2
2	Rencontre East	3	2015	3
			2018	3
3	Fortune Bay west	22	2014	8
			2017	9
			2018	1
4	Great Bay de l'Eau	4	2016	3
5	Harbour Breton Bay	4	2015	3
			2018	3
6	Connaigre Bay	2	–	0
7	Hermitage Bay	5	2014	3
			2017	2
8	Gaultois Passage	9	2016	3
9	Bay d'Espoir	11	2015	3
			2018	3
10	Facheux Bay	2	–	0
11	Hare Bay, Devil Bay, Rencontre West	1	2014	1

Table 5. Number of Canadian marine finfish farms using drugs and pesticides, by category and province, 2016-2018. The categories are: antibiotic drugs (in-feed), pest control drugs (in-feed), and pesticides (bath treatment). Data on chemical use were obtained from the NAPRD marine finfish data (DFO 2020b), also included were two trials using the pest control drug selamectin (one farm in NB in 2017; one farm in NB in 2018).

		Number of farms using drugs and pesticides from each category										
Prov.	Number of farms in NAPRD	No drugs or pesticides	1 or more drugs or pesticides	No antibiotic drugs	1 or more antibiotic drugs	Only antibiotic drugs	No pest control drugs	1 or more pest control drugs	Only pest control drugs	No pesti-cides	1 or more pesti-cides	Only pesti-cides
2016												
BC	78	11	67	37	41	27	43	35	17	67	11	3
NB	44	6	38	30	14	0	18	26	0	14	30	12
NS	8	6	2	6	2	2	8	0	0	8	0	0
NL	22	1	21	12	10	1	4	18	3	9	13	2
Totals	**152**	**24**	**128**	**85**	**67**	**30**	**73**	**79**	**20**	**98**	**54**	**17**
2017												
BC	81	14	67	41	40	20	43	38	18	64	17	4
NB	45	14	31	28	17	1	25	20	3	23	22	8
NS	11	11	0	11	0	0	11	0	0	11	0	0
NL	25	3	22	16	9	1	6	19	0	5	20	2
Totals	**162**	**42**	**120**	**96**	**66**	**22**	**85**	**77**	**21**	**103**	**59**	**14**
2018												
BC	73	10	63	33	40	22	41	32	12	51	22	6

Prov.	Number of farms in NAPRD	Number of farms using drugs and pesticides from each category										
		No drugs or pesticides	1 or more drugs or pesticides	No antibiotic drugs	1 or more antibiotic drugs	Only antibiotic drugs	No pest control drugs	1 or more pest control drugs	Only pest control drugs	No pesti-cides	1 or more pesti-cides	Only pesti-cides
NB	36	8	28	24	12	1	16	20	2	15	21	5
NS	8	5	3	5	3	3	8	0	0	8	0	0
NL	19	5	14	15	4	2	8	11	2	9	10	1
Totals	**136**	**28**	**108**	**77**	**59**	**28**	**73**	**63**	**16**	**83**	**53**	**12**

Table 6. Number of Canadian marine finfish farms treated with sea louse control chemicals, by province, 2016-2018. The sea louse control drugs used were emamectin benzoate and ivermectin, and also two trials with selamectin. The sea louse control pesticides used were azamethiphos and hydrogen peroxide.

		Number of sea louse control drugs				Number of sea louse control pesticides				Number of sea louse control drug and pesticides					
Year	Province	0	1	2	Total	0	1	2	Total	0	1	2	3	4	Total
2016	BC	43	35	0	78	67	11	0	78	38	34	6	0	0	78
	NB	18	17	9	44	14	17	13	44	6	15	9	11	3	44
	NS	8	0	0	8	8	0	0	8	8	0	0	0	0	8
	NL	4	16	2	22	9	13	0	22	2	9	9	2	0	22
	Canada	73	68	11	152	98	41	13	152	54	58	24	13	3	152
2017	BC	43	38	0	81	64	17	0	81	34	39	8	0	0	81
	NB	25	16	4	45	23	15	7	45	15	15	8	6	1	45
	NS	11	0	0	11	11	0	0	11	11	0	0	0	0	11
	NL	6	16	3	25	5	16	4	25	4	2	13	6	0	25
	Canada	85	70	7	162	103	48	11	162	64	56	29	12	1	162
2018	BC	41	32	0	73	51	22	0	73	32	28	13	0	0	73
	NB	16	13	7	36	15	21	0	36	9	10	13	4	0	36
	NS	8	0	0	8	8	0	0	8	8	0	0	0	0	8
	NL	8	10	1	19	9	6	4	19	7	3	5	3	1	19
	Canada	73	55	8	136	83	49	4	136	56	41	31	7	1	136

Table 7. Number of Canadian marine finfish farms using drugs and pesticides from two or more categories, by province, 2016-2018. The three categories are: antibiotic drugs (in-feed), pest control drugs (in-feed), and pesticides (bath treatment). Data on chemical use were obtained from the NAPRD marine finfish data (DFO 2020b), adjusted to include two trials using the pest control drug selamectin (one farm in NB in 2017; one farm in NB in 2018).

		Number of farms reporting use of drugs and pesticides per category							
					2 categories				3 categories: antibiotics, pest control drugs & pesticides
Province	Number of farms in NAPRD	1 or more drugs or pesticides	1 category only	More than 1 category	Antibiotics & pest control drugs	Antibiotics & pesticides	Pest control drugs & pesticides	Subtotal	
2016									
BC	78	67	47	20	12	2	6	20	0
NB	44	38	12	26	8	0	12	20	6
NS	8	2	2	0	0	0	0	0	0
NL	22	21	6	15	4	0	6	10	5
Totals	**152**	**128**	**67**	**61**	**24**	**2**	**24**	**50**	**11**
2017									
BC	81	67	42	25	12	5	5	22	3
NB	45	31	12	19	5	2	3	10	9
NS	11	0	0	0	0	0	0	0	0
NL	25	22	3	19	1	0	11	12	7
Totals	**162**	**120**	**57**	**63**	**18**	**7**	**19**	**44**	**19**
2018									

Province	Number of farms in NAPRD	Number of farms reporting use of drugs and pesticides per category							
		1 or more drugs or pesticides	1 category only	More than 1 category	2 categories				3 categories: antibiotics, pest control drugs & pesticides
					Antibiotics & pest control drugs	Antibiotics & pesticides	Pest control drugs & pesticides	Subtotal	
BC	73	63	40	23	7	3	5	15	8
NB	36	28	8	20	4	2	9	15	5
NS	8	3	3	0	0	0	0	0	0
NL	19	14	5	9	0	0	7	7	2
Totals	**136**	**108**	**56**	**52**	**11**	**5**	**21**	**37**	**15**

Table 8. Number of Canadian marine finfish farms using drugs and pesticides, by treatment type (in-feed or bath) and province, 2016-2018. In-feed treatments were used for antibiotic drugs and pest control drugs. Bath treatments were used for pesticides. Data on chemical use were obtained from the NAPRD marine finfish data (DFO 2020b), adjusted to include two trials using the pest control drug selamectin (one farm in NB in 2017; one farm in NB in 2018).

		Number of farms reporting use of drugs and pesticides per treatment type								
				1 or more in-feed treatments						
Province	Number of farms in NAPRD	No treatments	1 or more treatments	Anti-biotics	Pest control drugs	Any in-feed drugs	Only in-feed treatments	1 or more bath treatments	Only bath treatments	Both in-feed & bath treatments
2016										
BC	78	11	67	41	35	64	56	11	3	8
NB	44	6	38	14	26	26	8	30	12	18
NS	8	6	2	2	0	2	2	0	0	0
NL	22	1	21	10	18	19	8	13	2	11
Totals	**152**	**24**	**128**	**67**	**79**	**111**	**74**	**54**	**17**	**37**
2017										
BC	81	14	67	40	38	63	50	17	4	13
NB	45	14	31	17	20	22	8	22	8	14
NS	11	11	0	0	0	0	0	0	0	0
NL	25	3	22	9	19	20	2	20	2	18
Totals	**162**	**42**	**120**	**66**	**77**	**105**	**60**	**59**	**14**	**45**
2018										
BC	73	10	63	40	32	57	41	22	6	16

Province	Number of farms in NAPRD	Number of farms reporting use of drugs and pesticides per treatment type								
				1 or more in-feed treatments						
		No treatments	1 or more treatments	Anti-biotics	Pest control drugs	Any in-feed drugs	Only in-feed treatments	1 or more bath treatments	Only bath treatments	Both in-feed & bath treatments
NB	36	8	28	12	20	23	7	21	5	16
NS	8	5	3	3	0	3	3	0	0	0
NL	19	5	14	4	11	13	4	10	1	9
Totals	**136**	**28**	**108**	**59**	**63**	**96**	**55**	**53**	**12**	**41**

Table 9. Number of months per year when drug and pesticide treatments occurred at Canadian marine finfish farm, by province, 2016-2018. Values shown are means and maxima for all treated farms, per province and year, based on treatment start and end dates reported in the Aquaculture Integrated Information System (AQUIIS); except 56% of BC treatment entries in 2016 did not include end dates (37 of 38 treatment entries for emamectin benzoate; 34 of 38 entries for florfenicol; all 16 entries for hydrogen peroxide). n = number of treated farms.

	2016			2017			2018		
		No. of months			No. of months			No. of months	
	n	Mean	Max.	n	Mean	Max.	n	Mean	Max.
All drugs and pesticides									
BC	67	2.3	5	67	2.5	8	63	3.1	7
NB	38	5.5	10	31	4.5	8	28	3.3	7
NS	2	1.0	1	0	–	–	3	1.3	2
NL	21	4.1	7	22	5.4	7	14	3.6	6
Antibiotic drugs: Oxytetracycline									
BC	8	1.6	2	7	2.1	5	10	1.7	6
NB	10	1.6	3	5	1.6	2	5	1.0	1
NS	2	1.0	1	0	–	–	2	1.5	2
NL	4	1.5	2	5	1.6	3	0	–	–
Antibiotic drugs: Florfenicol									
BC	35	2.4	5	35	2.4	6	35	3.0	5
NB	7	1.6	3	11	1.5	2	8	1.3	2
NS	0	–	–	0	–	–	1	1.0	1
NL	5	2.4	4	4	2.0	3	4	1.8	2
Pest control drugs: Emamectin benzoate									
BC	35	1.1	2	38	1.5	4	32	1.3	2
NB	21	3.5	8	10	4.6	7	12	2.3	7
NS	0	–	–	0	–	–	0	–	–
NL	14	2.7	5	13	2.7	5	11	3.6	5

	2016			2017			2018		
		No. of months			No. of months			No. of months	
	n	Mean	Max.	n	Mean	Max.	n	Mean	Max.
Pest control drugs: Ivermectin									
BC	0	–	–	0	–	–	0	–	–
NB	14	5.1	7	13	3.9	5	13	3.0	5
NS	0	–	–	0	–	–	0	–	–
NL	6	4.7	5	9	5.6	6	1	2.0	2
Pesticides: Azamethiphos									
BC	0	–	–	0	–	–	0	–	–
NB	29	3.5	8	18	2.7	5	11	1.5	3
NS	0	–	–	0	–	–	0	–	–
NL	13	2.2	4	20	3.4	6	10	2.8	4
Pesticides: Hydrogen peroxide									
BC	11	1.5	3	17	1.5	3	22	1.4	3
NB	14	1.6	3	9	1.2	3	11	1.2	2
NS	0	–	–	0	–	–	0	–	–
NL	0	–	–	4	1.3	2	4	1.0	1

FIGURES

Figure 1. Locations of marine finfish aquaculture licences in Canada in 2018 (•), including active and inactive sites. Farms are located in British Columbia (BC), New Brunswick (NB), Nova Scotia (NS), and Newfoundland & Labrador (NL). Data sources: DFO (2019a); NBDAAF (2020); NSDFA (2020); NLDFLR (2019a).

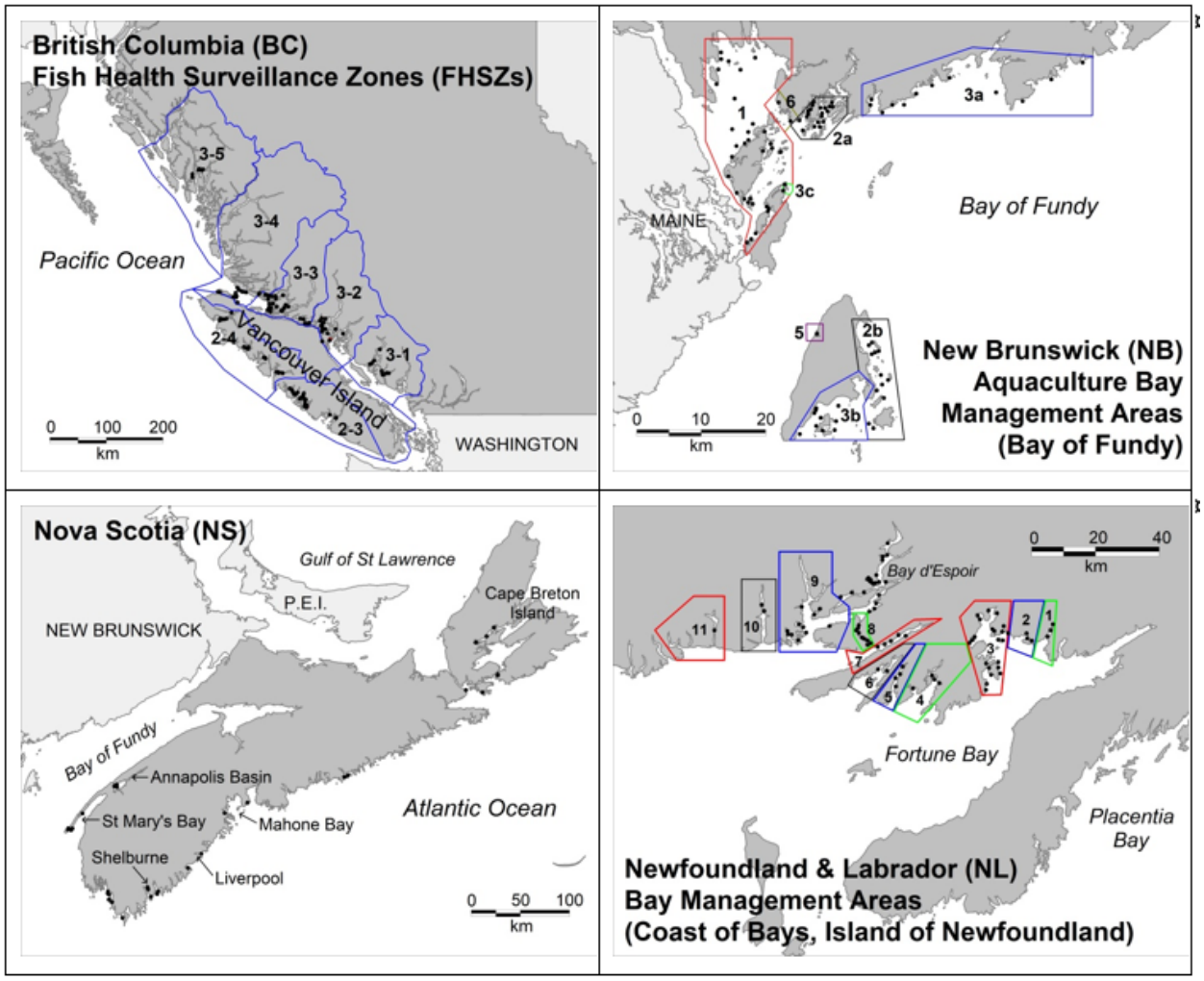

Figure 2. Management areas relevant to marine finfish aquaculture in Canada. Top left: British Columbia (BC) – Fish Health Surveillance Zones (FHSZs). Top right: New Brunswick (NB) – Aquaculture Bay Management Areas (BMAs) in the lower Bay of Fundy; BMA 3c was created in 2017 (it was formerly part of BMA 1); BMA 5 holds one non-commercial site; BMA 6 is designated for non-salmonid aquaculture but has been inactive since 2011. Bottom left: Nova Scotia (NS) – no designated management areas for aquaculture. Bottom right: Newfoundland & Labrador (NL) – BMAs for marine salmon farming in the Coast of Bays area on the south coast of the Island of Newfoundland; the brackish water inner Bay d'Espoir area (used for steelhead farming) is not included within the BMAs. Black symbols (•) represent licensed marine finfish farms in 2018.

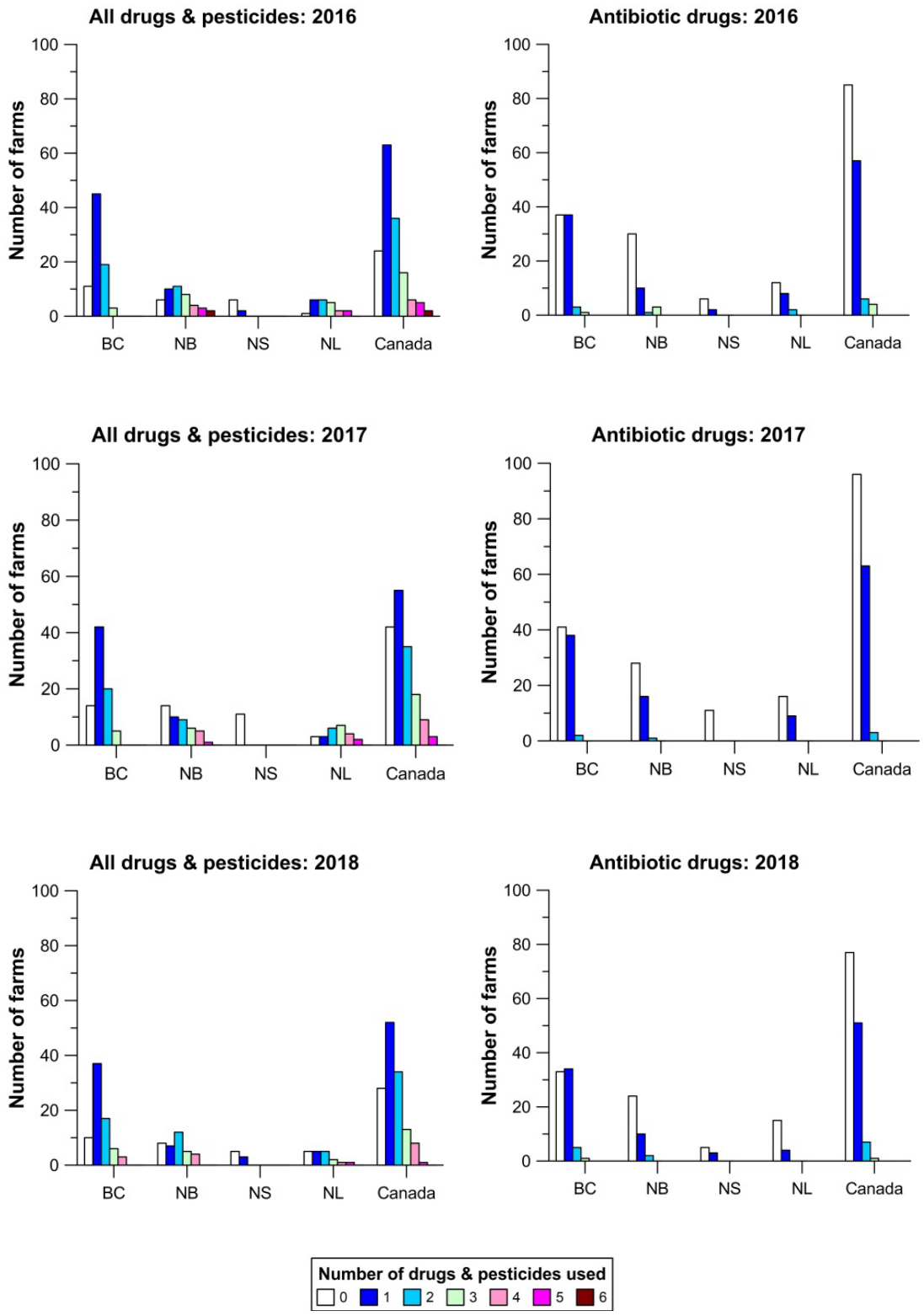

Figure 3 Number of Canadian marine finfish farms using of 0, 1, or more drugs and pesticides, by province, 2016-2018: all drugs and pesticides (left); antibiotic drugs (right).

Data source: NAPRD (DFO 2020b).

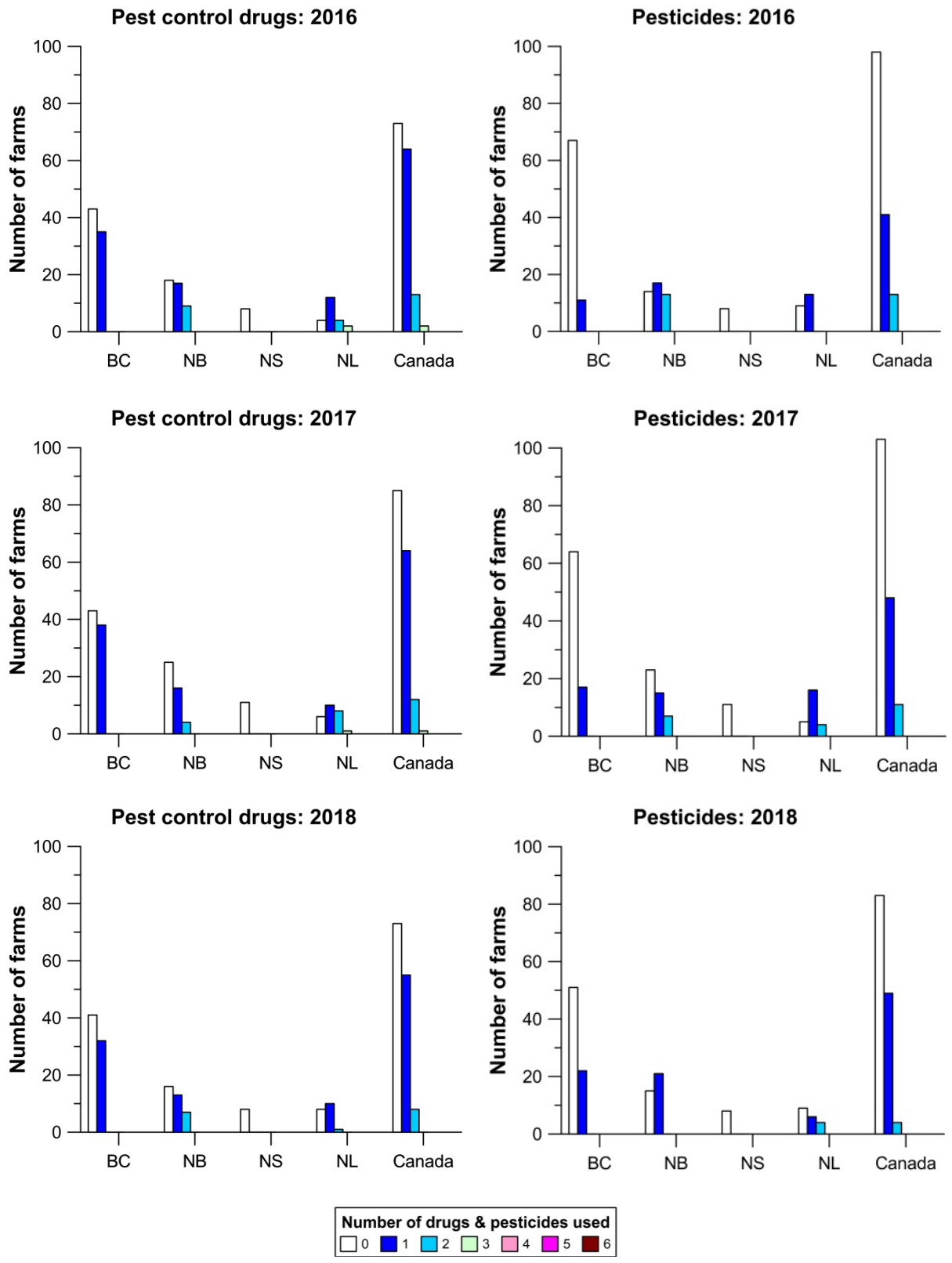

Figure 3 (cont'd). Number of Canadian marine finfish farms using of 0, 1, or more drugs and pesticides, by province, 2016-2018: pest control drugs (left); pesticides (right).

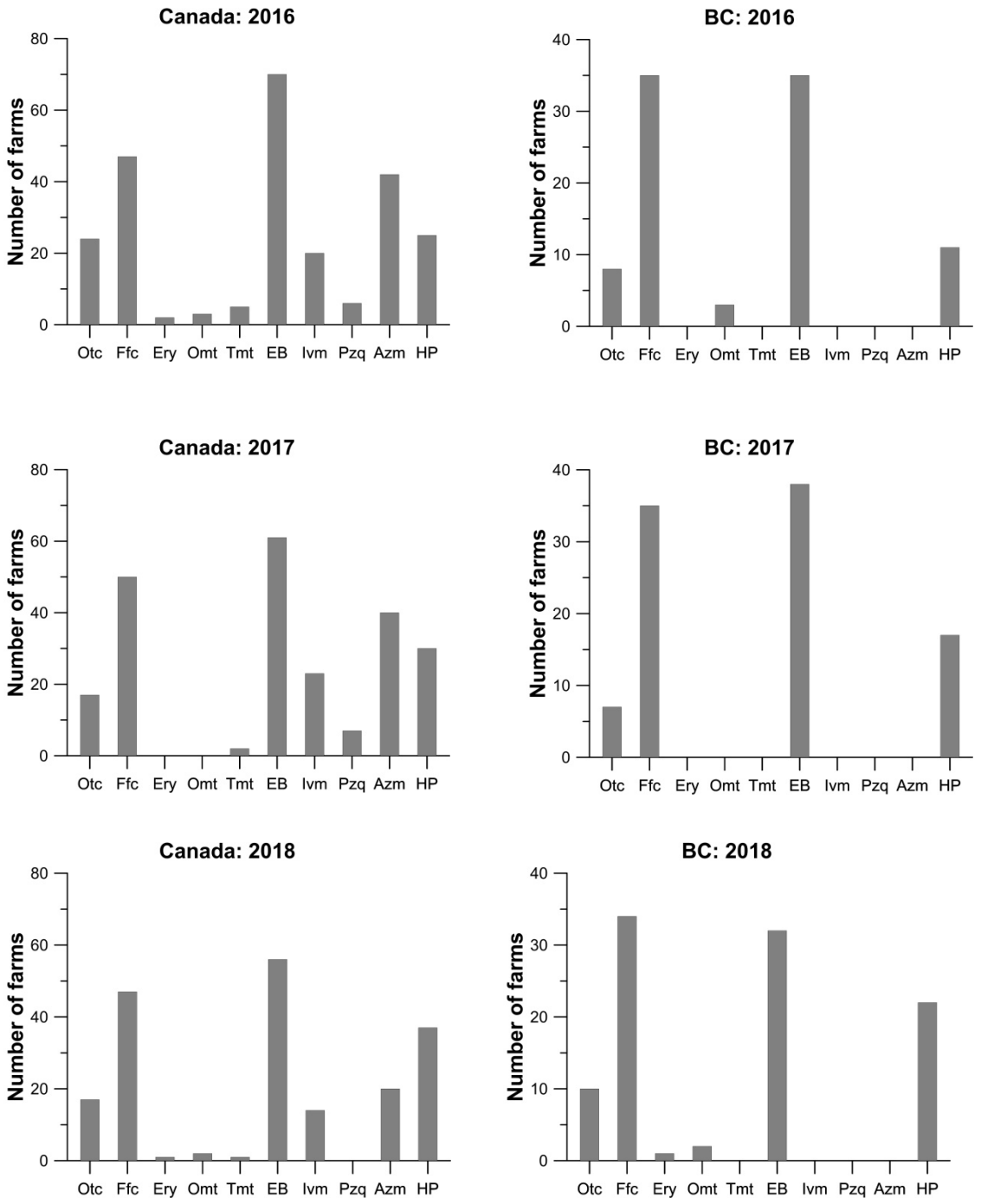

Figure 4. Number of Canadian marine finfish farms treated with each drug and pesticide, by province, 2016-2018: Canada totals (left); BC (right). The chemicals used were: oxytetracycline (Otc), florfenicol (Ffc), erythromycin (Ery), ormetoprim (Omt), trimethoprim (Tmt), emamectin benzoate (EB), ivermectin (Ivm), praziquantel (Pzq), azamethiphos (Azm), and hydrogen peroxide (HP). Ivermectin data include selamectin trials (one NB farm in 2017 and one NB farm in 2018). Data values are presented in Appendix A. Data source: NAPRD (DFO 2020b).

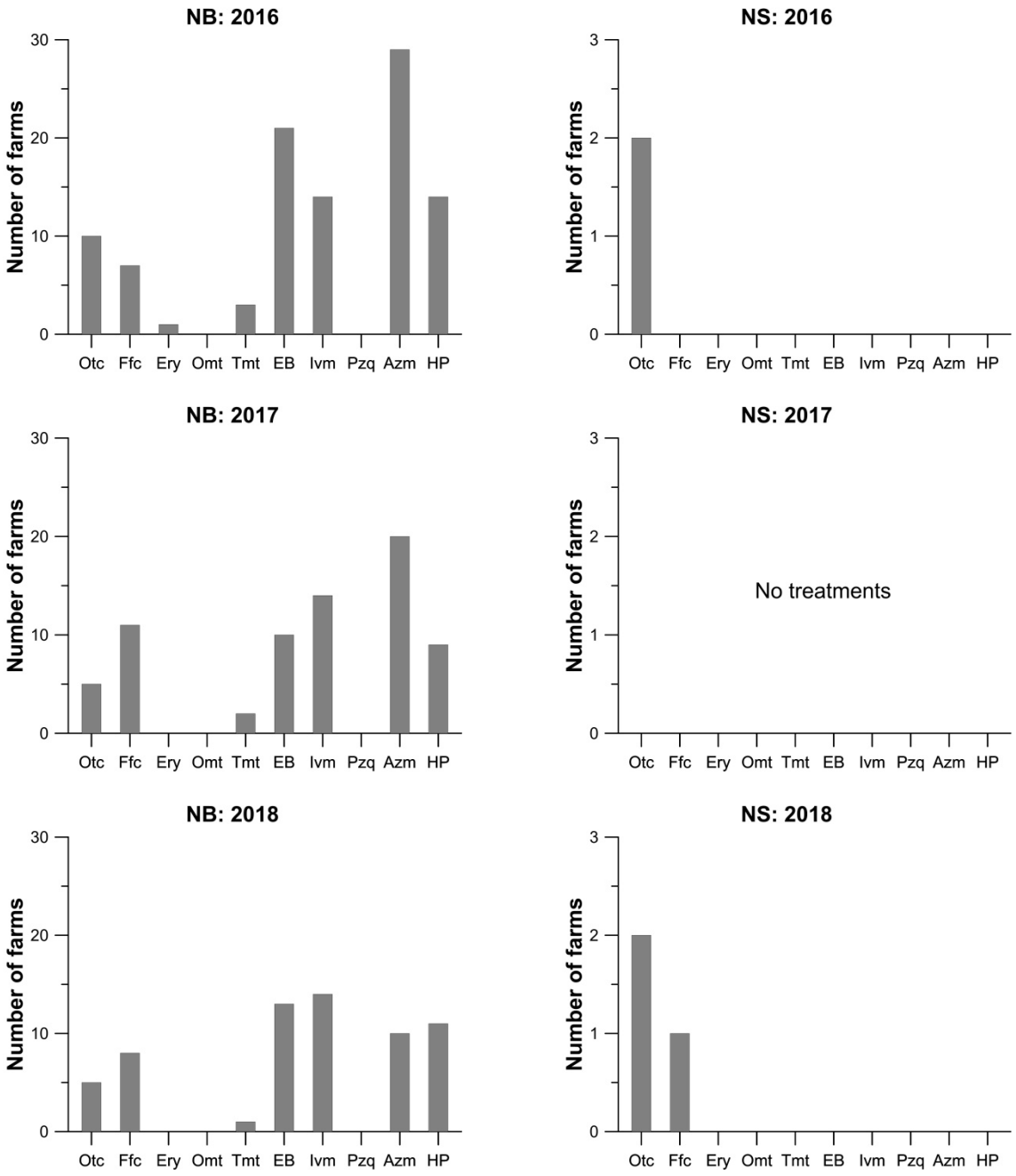

Figure 4 (cont'd). Number of Canadian marine finfish farms treated with each drug and pesticide, by province, 2016-2018: NB (left); NS (right). Ivermectin data for NB include selamectin trials (one farm in 2017 and one farm in 2018).

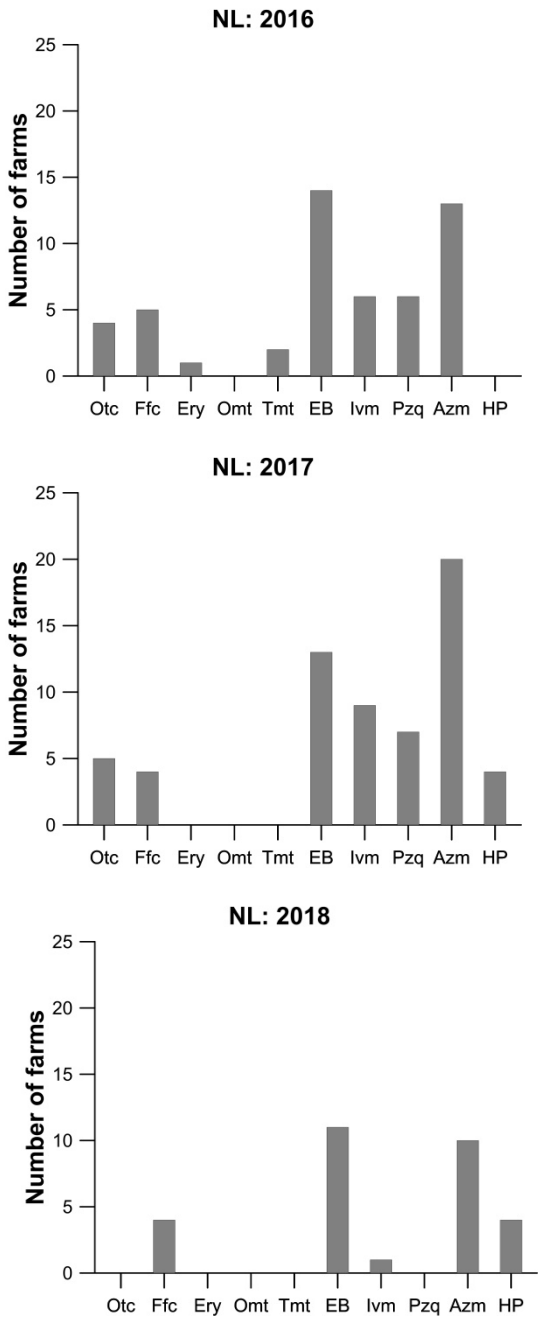

Figure 4. (concluded). Number of Canadian marine finfish farms treated with each drug and pesticide, by province, 2016-2018: NL.

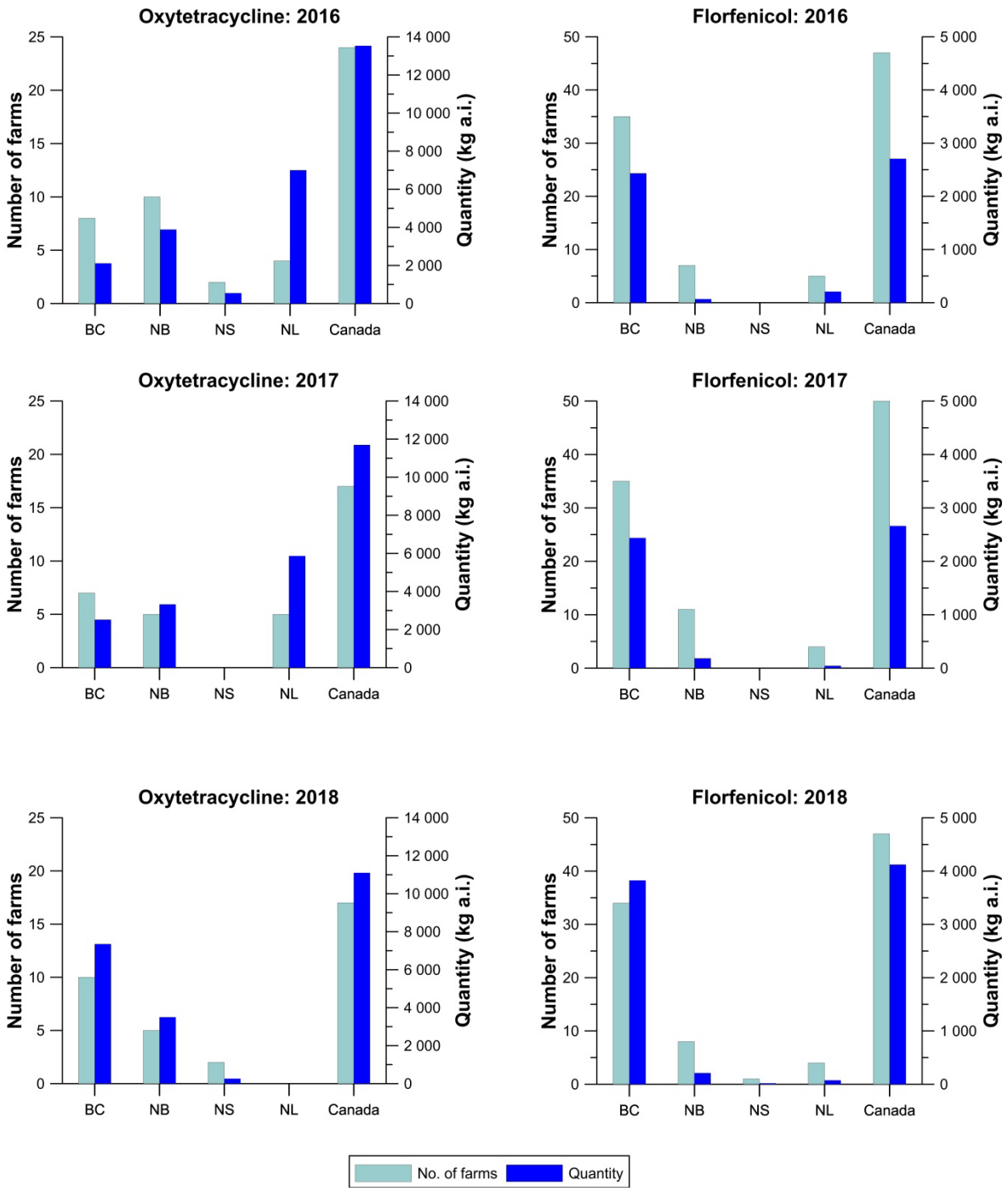

Figure 5. Antibiotic drug use at Canadian marine finfish farms, per province, 2016-2018: oxytetracycline (left) and florfenicol (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Graphs are not shown for the antibiotics erythromycin (2 farms in 2016, no farms in 2017, 1 farm in 2018), ormetoprim (3 farms in 2016, no farms in 2017, 2 farms in 2018), and trimethoprim (3 farms in 2016, 2 farms in 2017, 1 farm in 2018). Data values are presented in Appendix A. Data source: NAPRD (DFO 2020b).

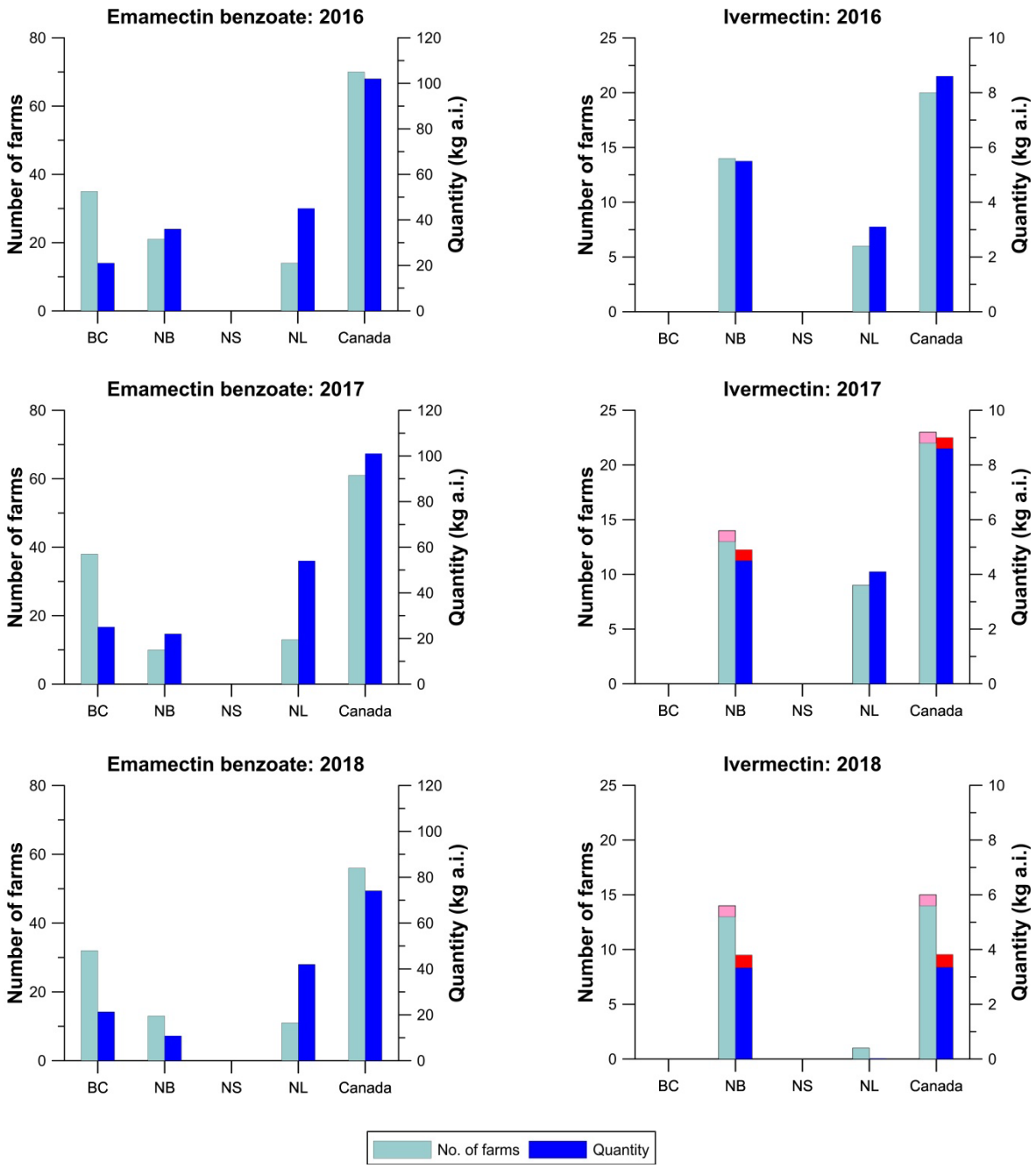

Figure 6. Pest control drug use at Canadian marine finfish farms, per province, 2016-2018: emamectin benzoate (left) and ivermectin (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Pink and red bars in the ivermectin graphs for 2017 and 2018 represent selamectin trials (one farm in NB in each year). Data values are presented in Appendix A. Data source: NAPRD (DFO 2020b).

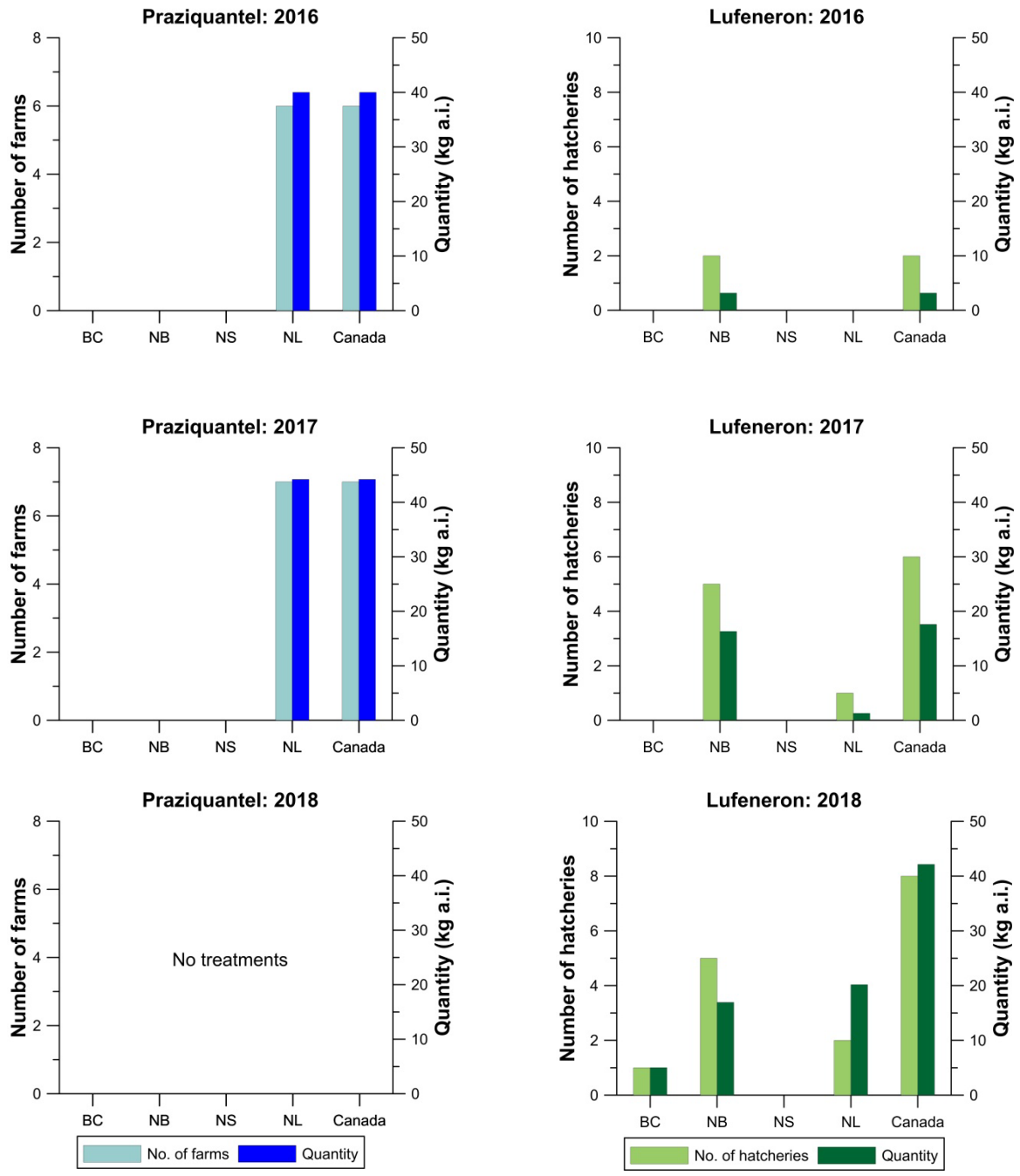

Figure 6. (cont'd). Pest control drug use at Canadian marine finfish farms, per province, 2016-2018: praziquantel (left) and lufeneron (right). Lufeneron is only used in freshwater hatcheries, but smolts treated in the hatcheries are transferred to marine farms.

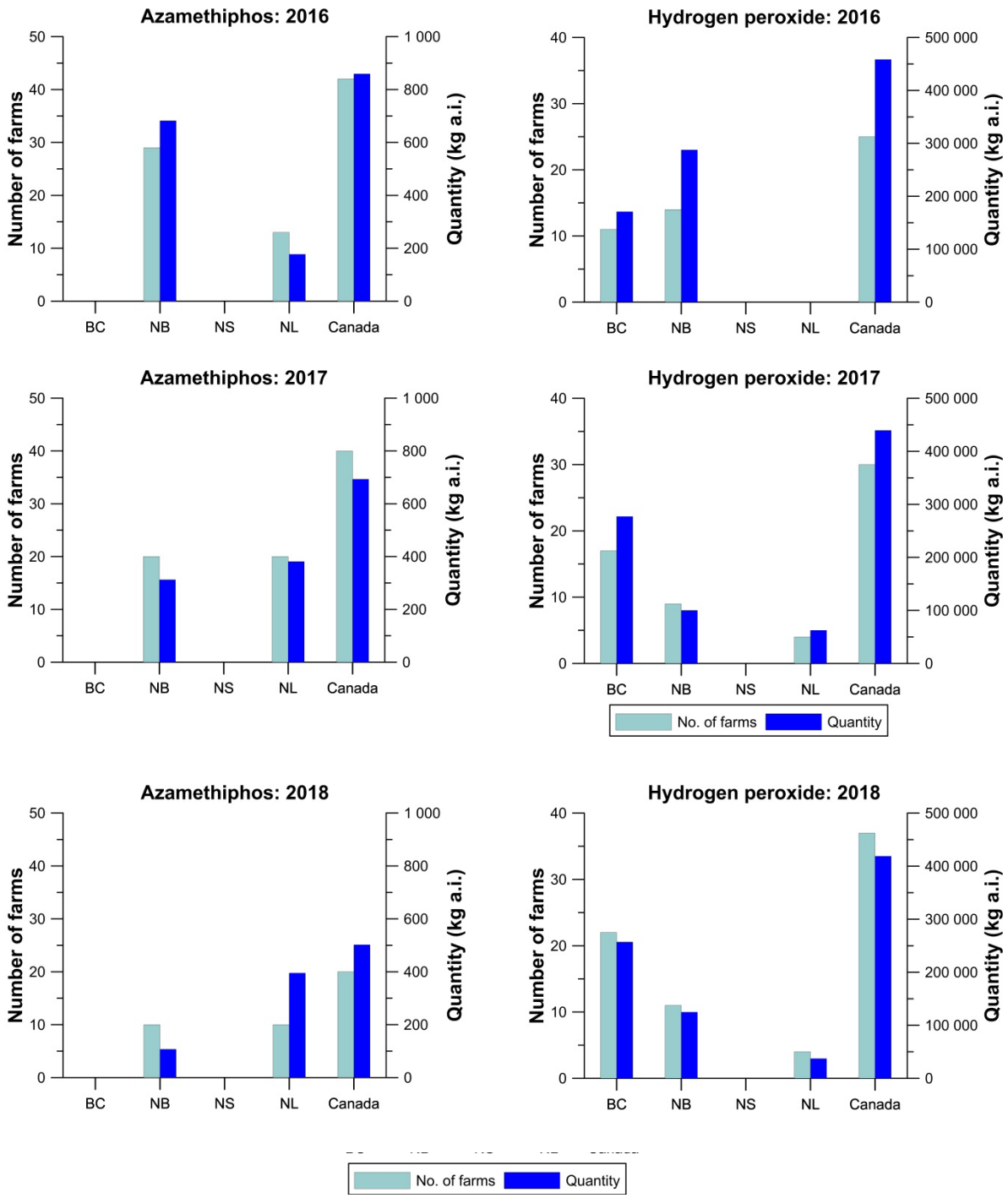

Figure 7. Pesticide use at Canadian marine finfish farms, per province, 2016-2018: azamethiphos (left) and hydrogen peroxide (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Data values are presented in Appendix A. Data source: NAPRD (DFO 2020b).

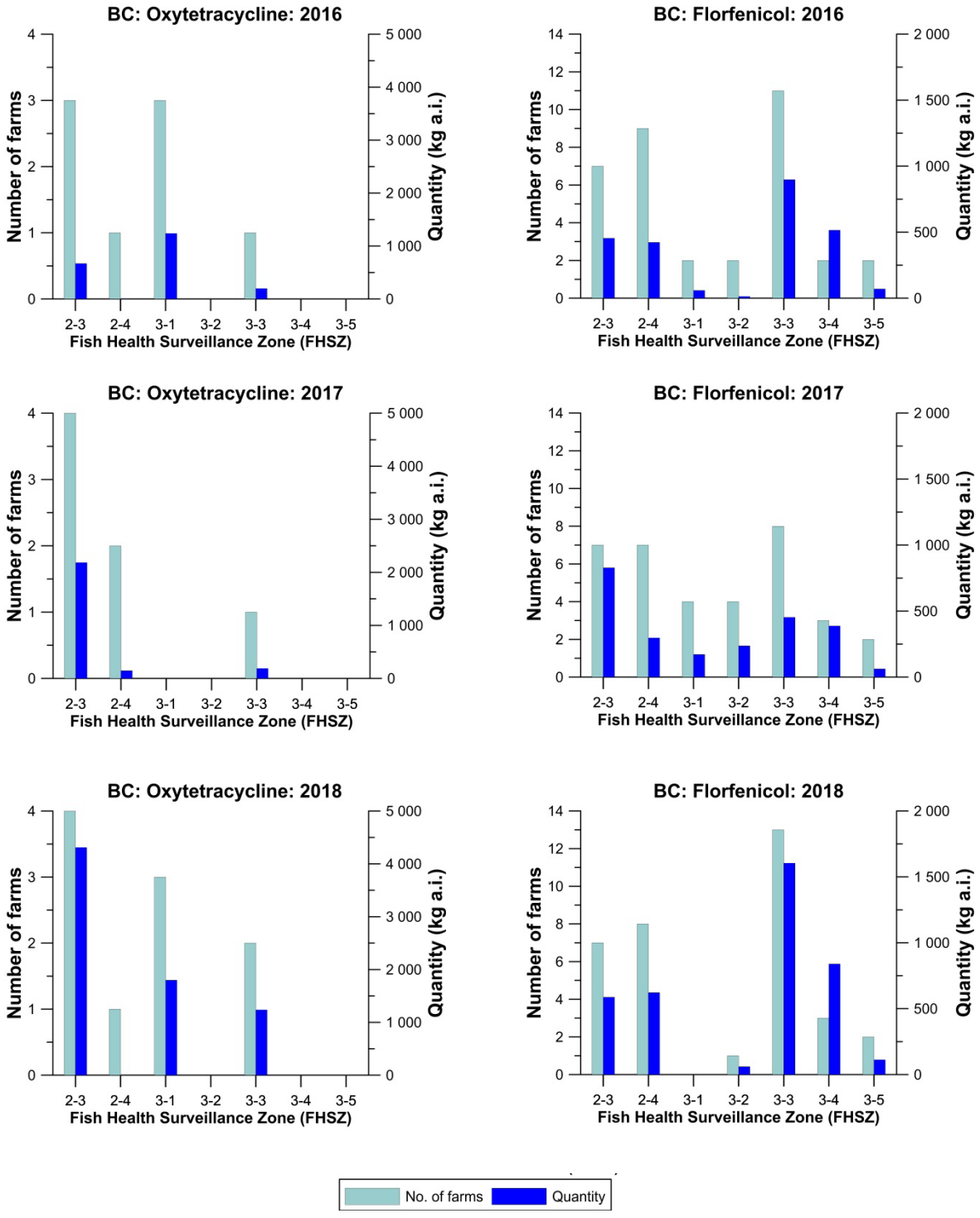

Figure 8. Drug and pesticide use at BC marine finfish farms, per Fish Health Surveillance Zone (FHSZ), 2016-2018: antibiotic drugs – oxytetracycline (left) and florfenicol (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Graphs are not shown for erythromycin (0 farms in 2016 and 2017, 1 farm in 2018), ormetoprim (3 farms in 2016, 0 farms in 2017, 2 farms in 2018); and trimethoprim (0 farms in 2016-2018). Maps showing locations of treated farms are in Appendix B. Data source: NAPRD (DFO 2020b).

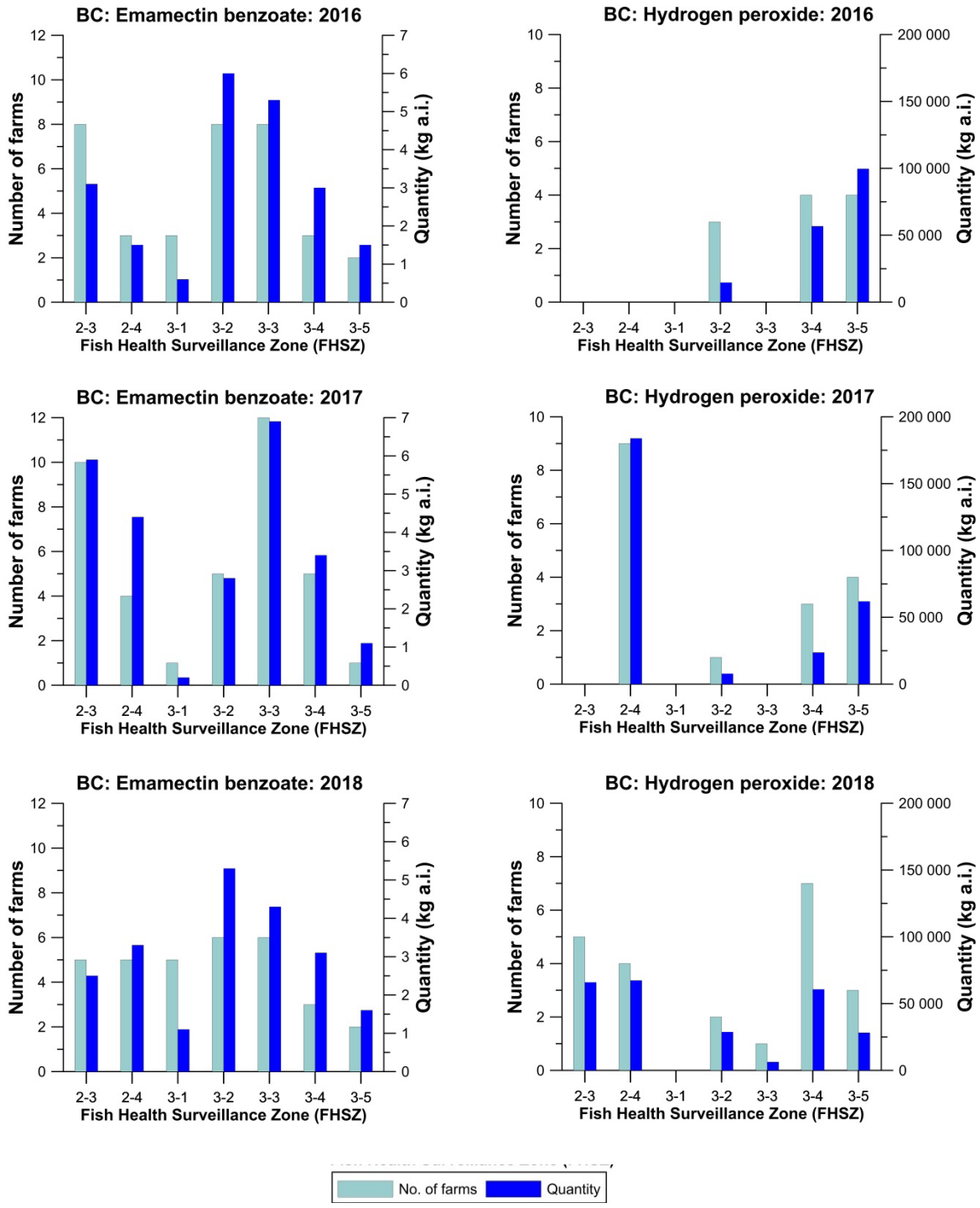

Figure 8. (cont'd). Drug and pesticide use at BC marine finfish farms, per Fish Health Surveillance Zone (FHSZ) in 2016-2018: pest control drugs – emamectin benzoate (left); pesticides – hydrogen peroxide (right). No other pest control drugs or pesticides were used in BC.

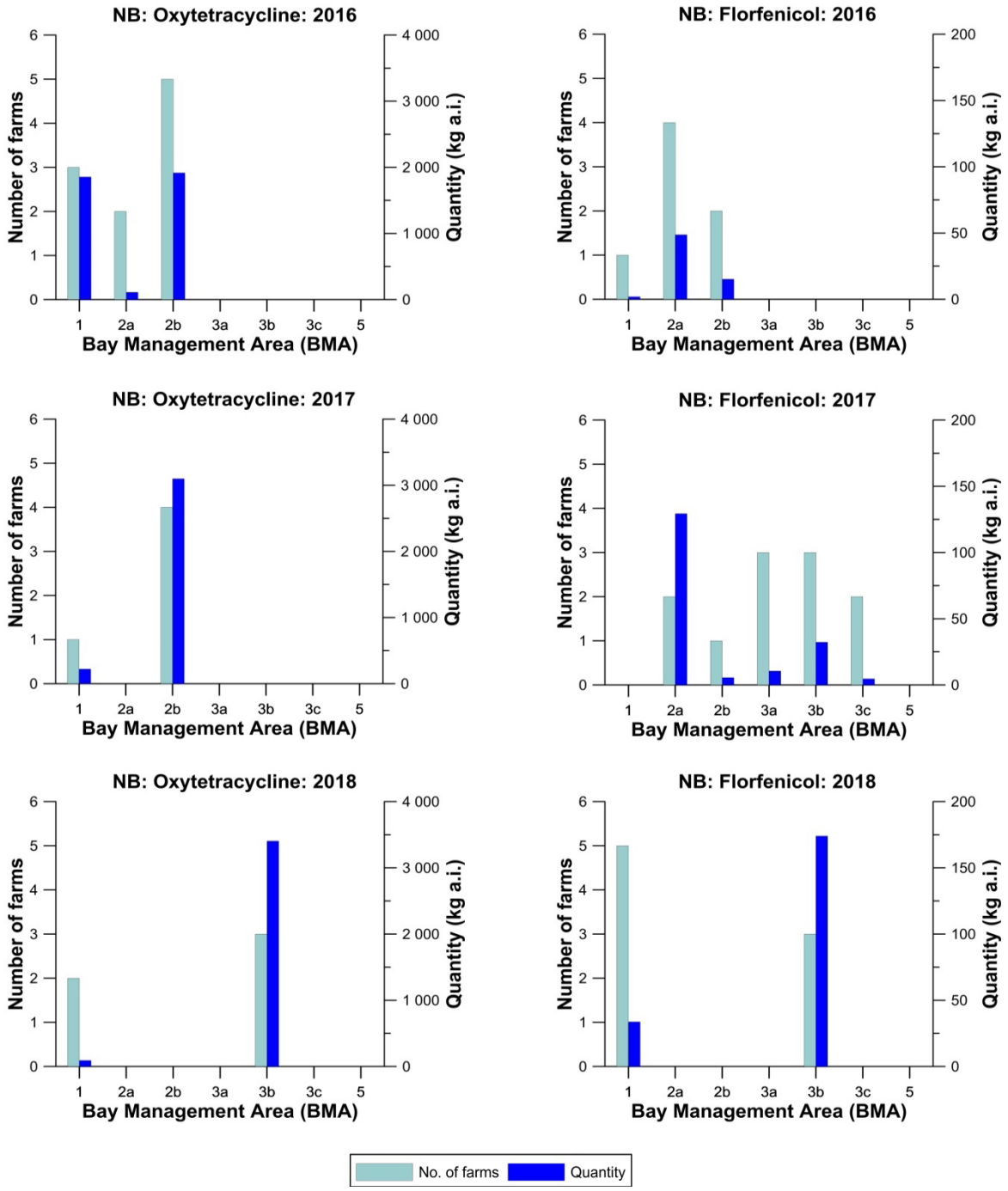

Figure 9. Drug and pesticide use at NB marine finfish farms, per Bay Management Area (BMA), 2016-2018: antibiotic drugs – oxytetracycline (left) and florfenicol (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Graphs are not shown for erythromycin (1 farm in 2016, 0 farms in 2017 and 2018), ormetoprim (0 farms in 2016-2018), and trimethoprim (3 farms in 2016, 2 farms in 2017, 1 farm in 2018). BMA 1 stocked in 2015 and 2018; BMAs 2a and 2b in 2016; BMAs 3a, 3b, and 3c in 2014 and 2017 (except one farm in BMA 3b stocked in 2014 and 2018, and BMA 3c did not stock in 2014). Maps showing locations of treated farms are in Appendix B. Data source: NAPRD (DFO 2020b).

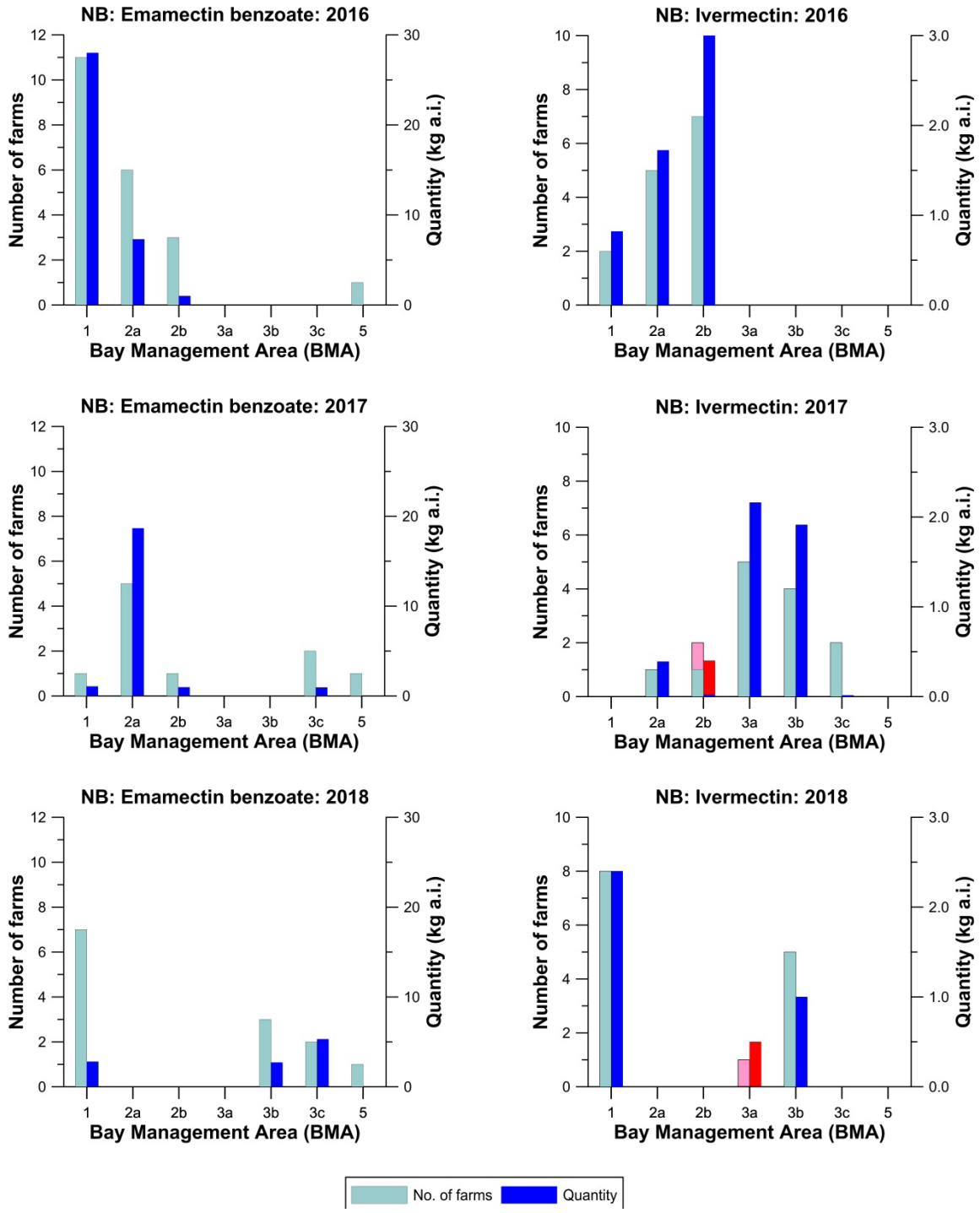

Figure 9. (cont'd). Drug and pesticide use at NB marine finfish farms, per Bay Management Area (BMA), 2016-2018: pest control drugs – emamectin benzoate (left) and ivermectin (right). Pink and red bars in the ivermectin graphs for 2017 and 2018 represent selamectin trials (one farm in BMA 2b in 2017 and one farm in BMA 3a in 2018).

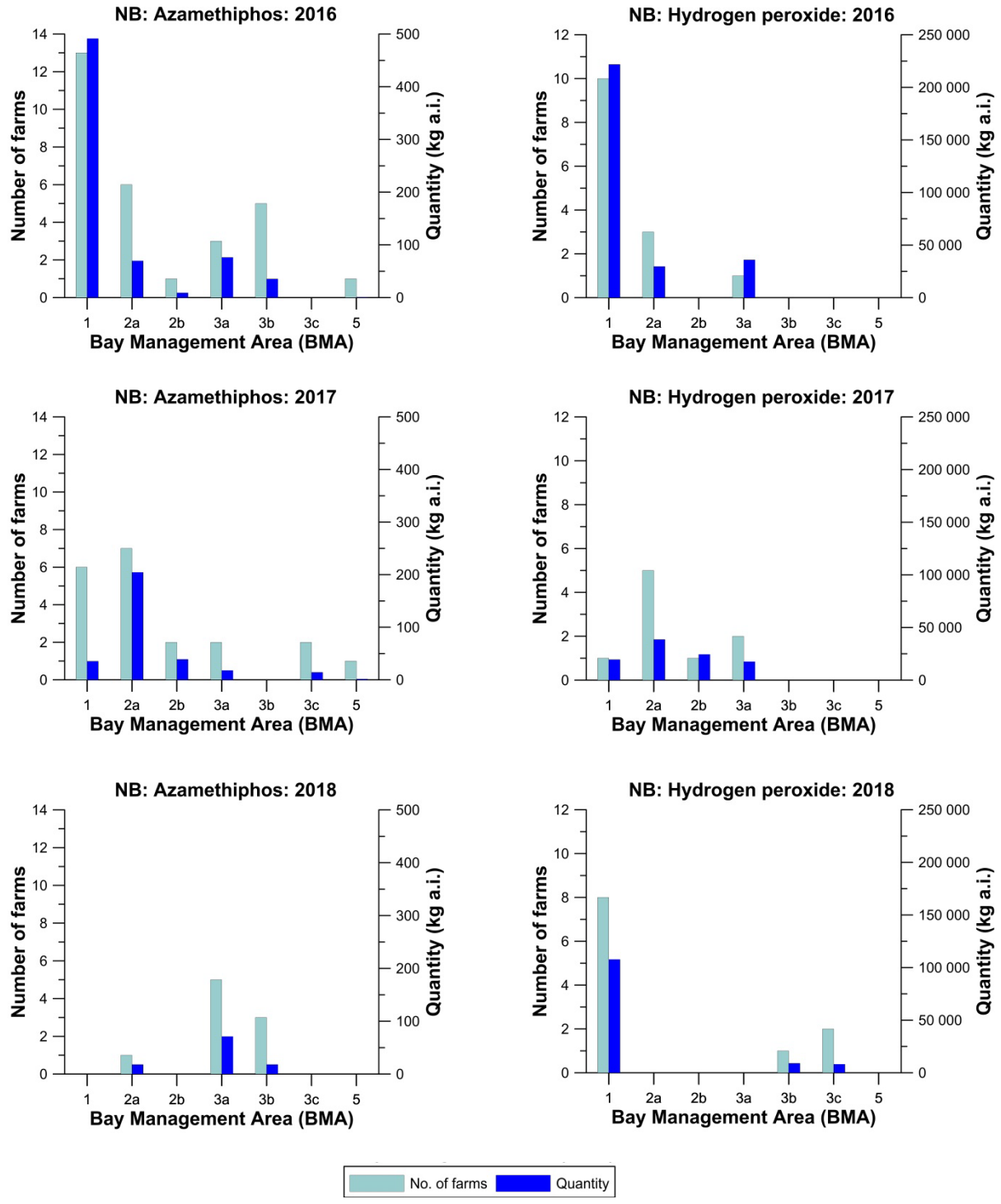

Figure 9. (concluded). Drug and pesticide use at NB marine finfish farms, per Bay Management Area (BMA), 2016-2018: pesticides – azamethiphos (left) and hydrogen peroxide (right).

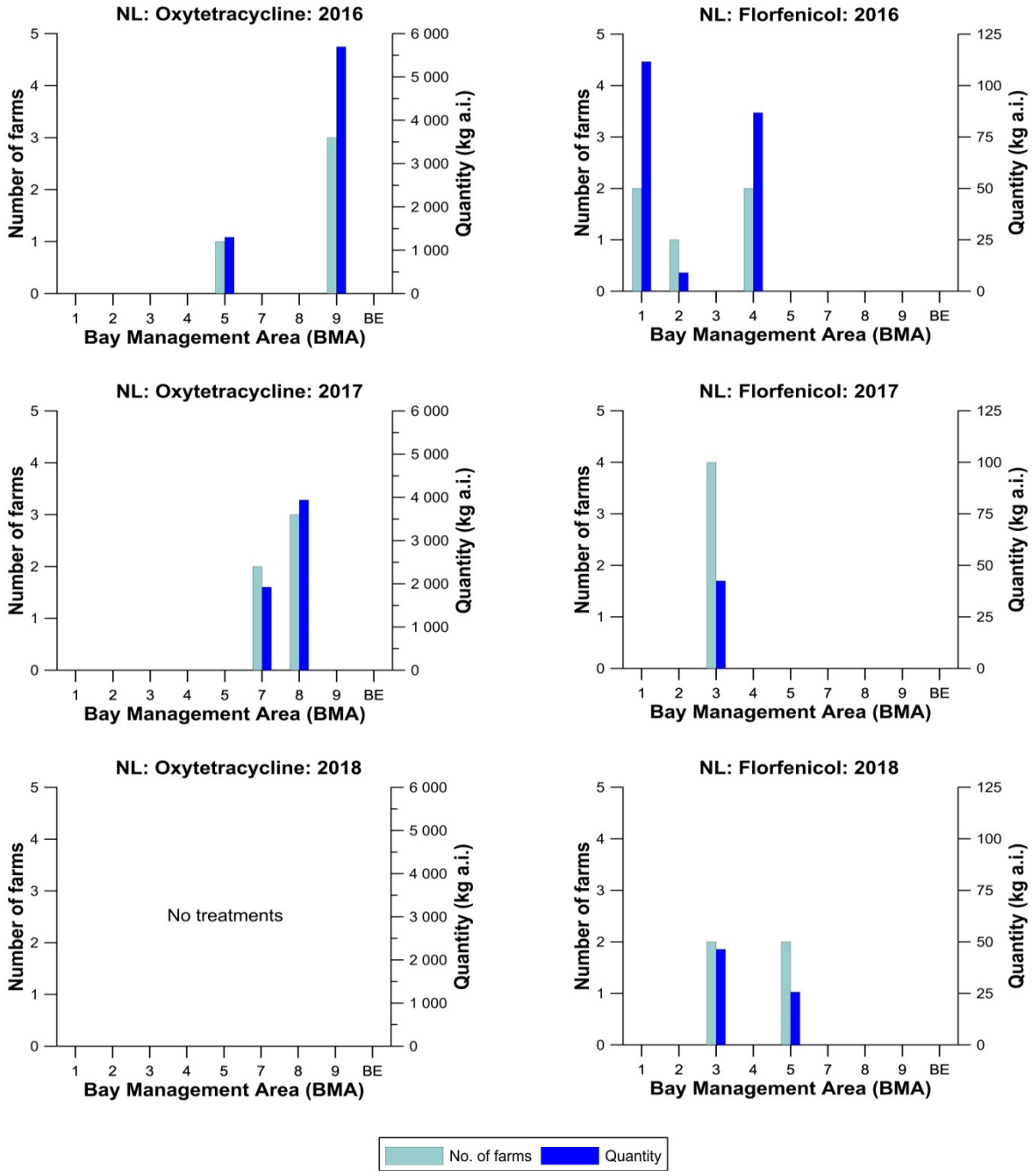

Figure 10. Drug and pesticide use at NL marine finfish farms, per Bay Management Area (BMA), 2016-2018: antibiotic drugs – oxytetracycline (left) and florfenicol (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Graphs are not shown for erythromycin (1 farm in 2016, 0 farms in 2017 and 2018), ormetoprim (0 farms in 2016-2018), and trimethoprim (2 farms in 2016, 0 farms in 2017 and 2018). BMAs are marine areas for growing Atlantic salmon: BMAs 1, 4, and 8 stocked in 2016; BMAs 2, 5, and 9 in 2015 and 2018; BMAs 3 and 7 in 2014 and 2017 (except one farm in BMA 3 stocked in 2014 and 2018); BMA 11 in 2014 (only 1 farm, which did not treat during 2016-2018); and there were no active farms in BMAs 6 and 10. Inner Bay d'Espoir (BE) is a brackish area for growing steelhead. Maps showing locations of treated farms are in Appendix B. Data source: NAPRD (DFO 2020b).

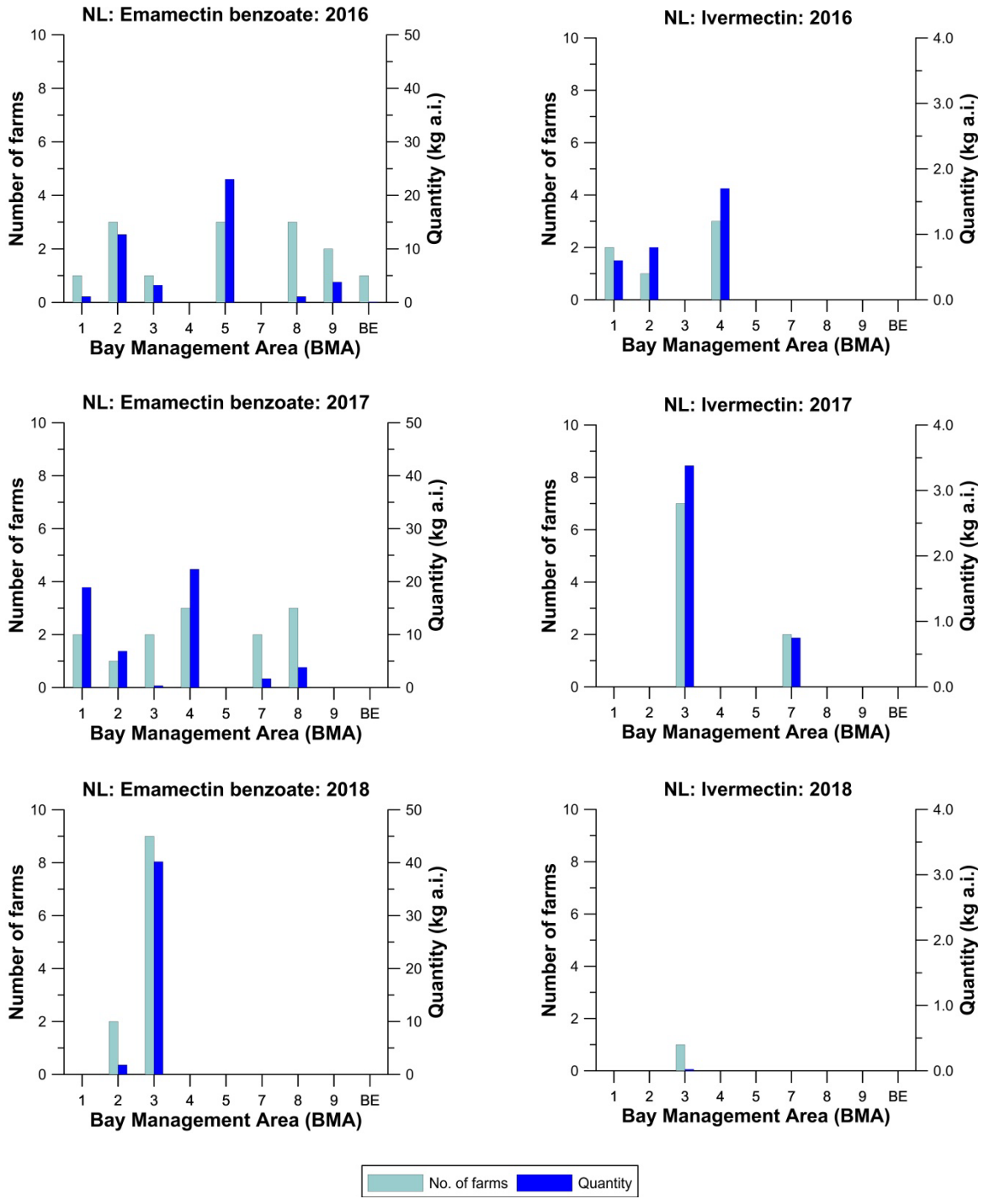

Figure 10. (cont'd). Drug and pesticide use at NL marine finfish farms, per Bay Management Area (BMA), 2016-2018: pest control drugs – emamectin benzoate (left) and ivermectin (right).

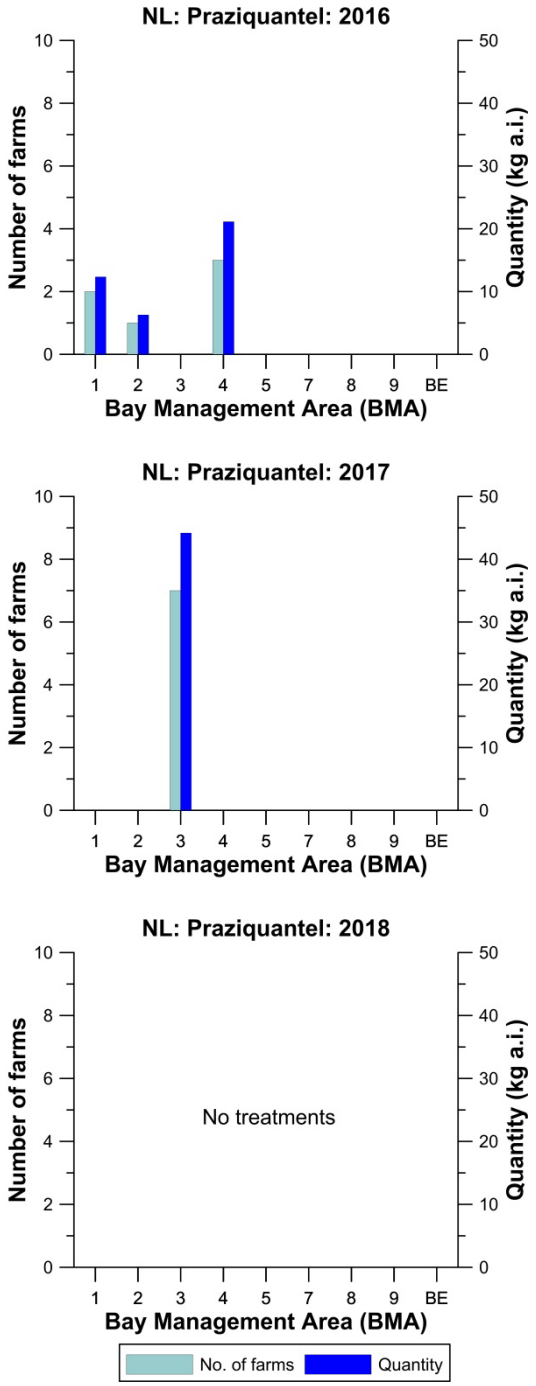

Figure 10. (cont'd). Drug and pesticide use at NL marine finfish farms, per Bay Management Area (BMA), 2016-2018: pest control drugs – praziquantel.

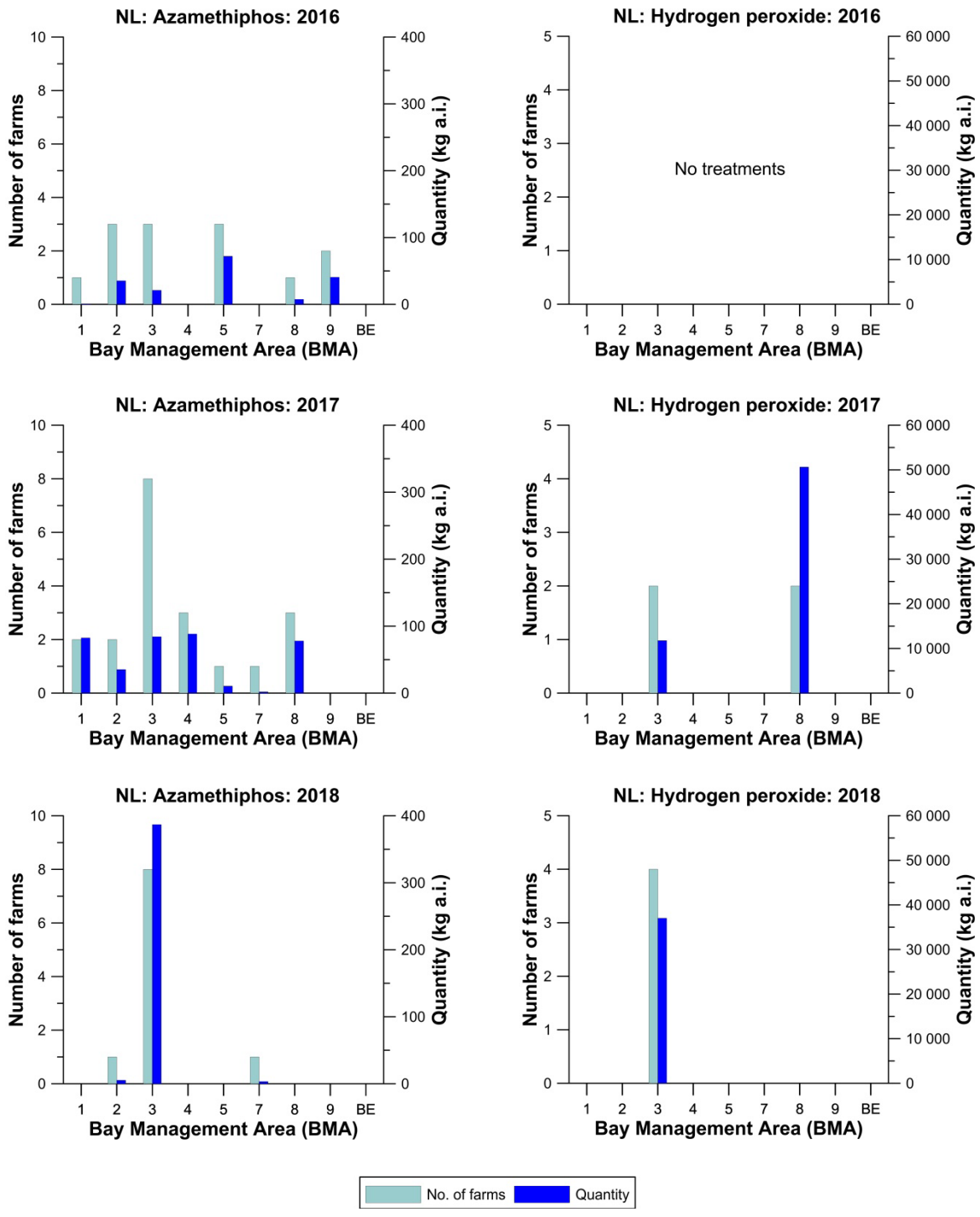

Figure 10. (concluded). Drug and pesticide use at NL marine finfish farms, per Bay Management Area (BMA), 2016-2018: pesticides – azamethiphos (left) and hydrogen peroxide (right).

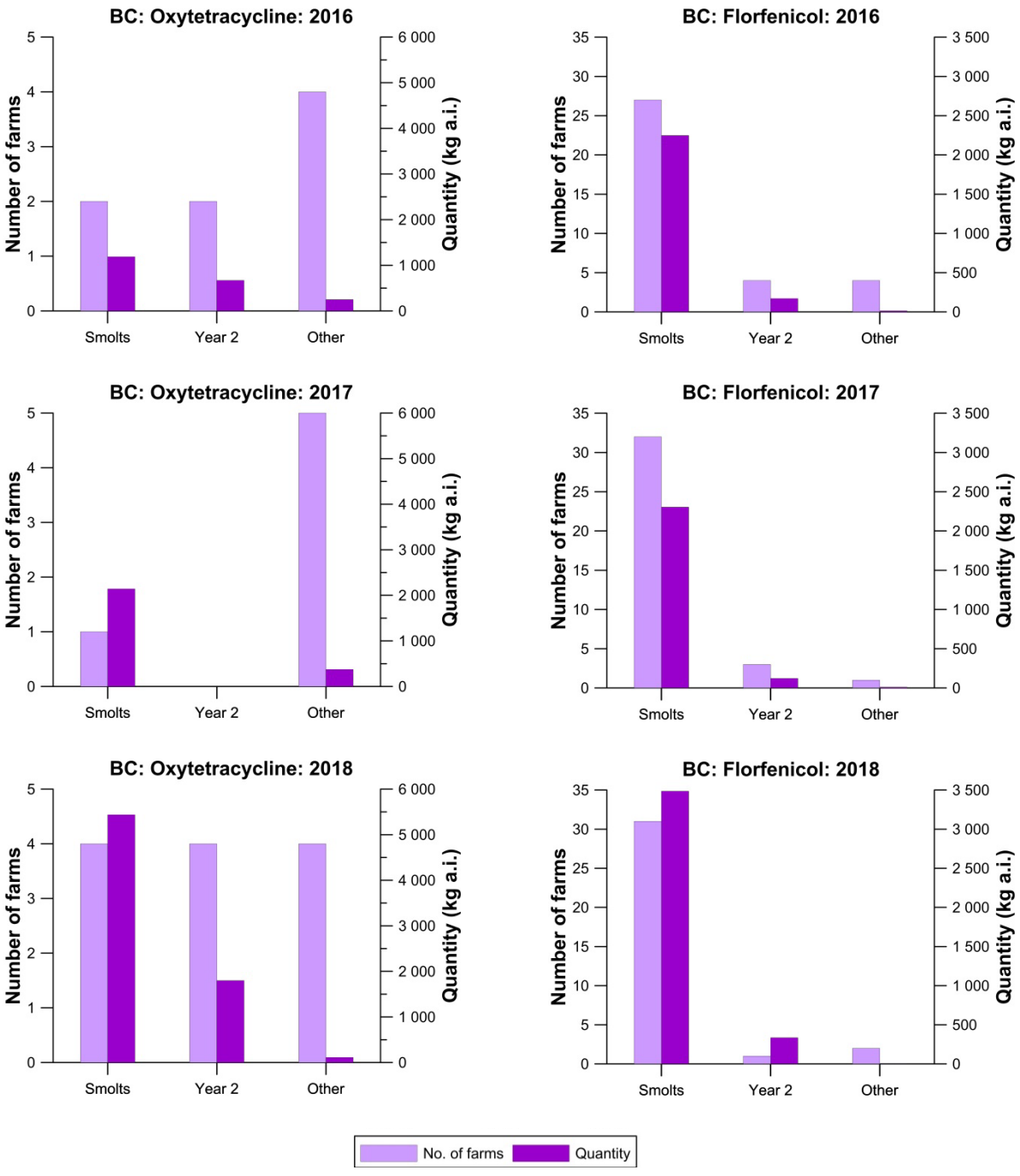

Figure 11. Drug and pesticide use at BC marine finfish farms, per year-class, 2016-2018: antibiotic drugs – oxytetracycline (left) and florfenicol (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Smolts are Atlantic salmon have been ≤12 months in seawater (since transfer from freshwater hatcheries). 'Year 2' represents Atlantic salmon that have been in seawater 13-24 months (marine growout times for Atlantic salmon in BC rarely exceed 24 months). The "Other" category includes farms holding Atlantic salmon broodstock or species other than Atlantic salmon (primarily Chinook salmon). Data sources: NAPRD (DFO 2020b); K. Sandberg (DFO, Campbell River, BC, pers. comm.).

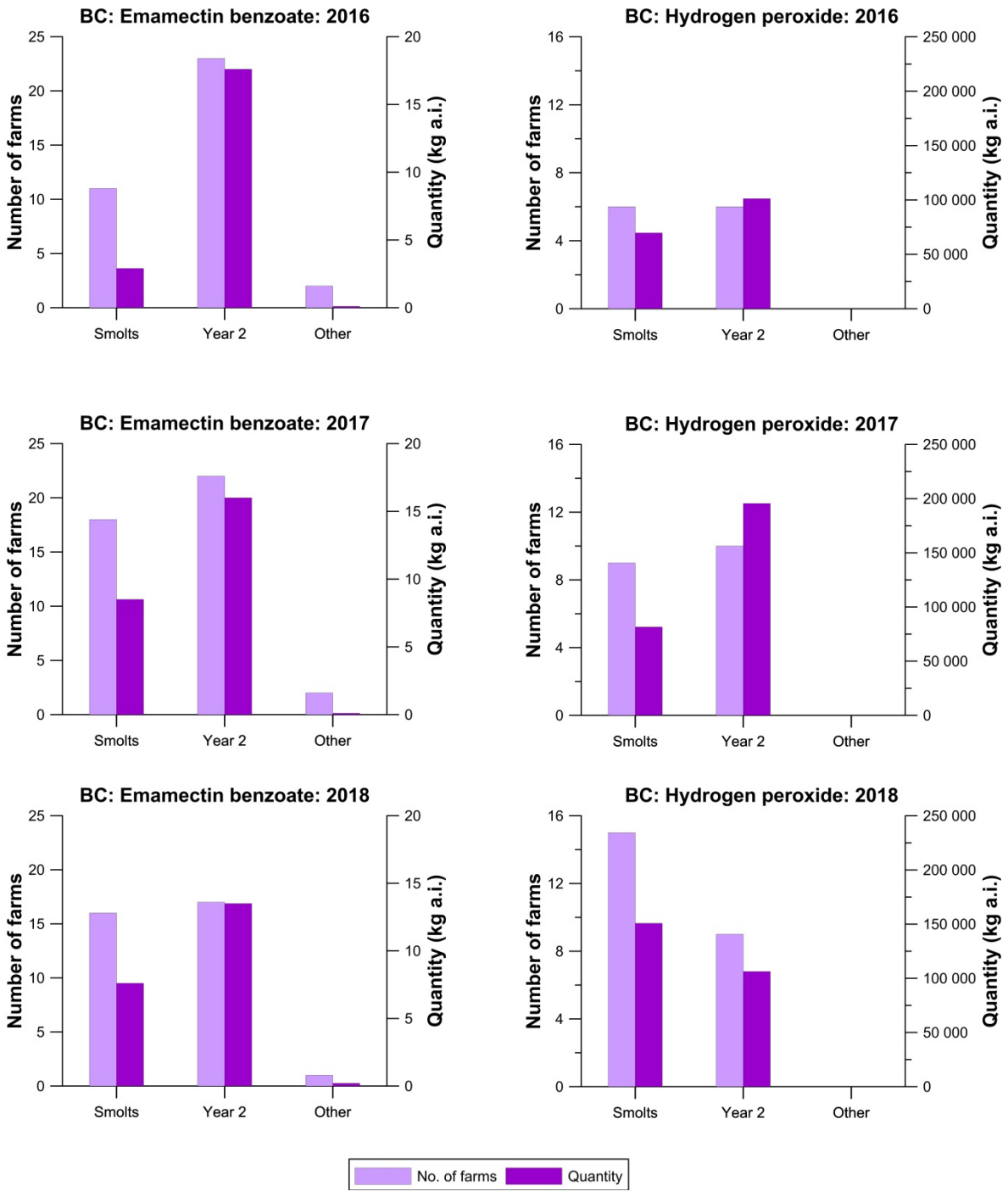

Figure 11. (cont'd). Drug and pesticide use at BC marine finfish farms, per year-class, 2016-2018: pest control drugs – emamectin benzoate (left); pesticides – hydrogen peroxide (right).

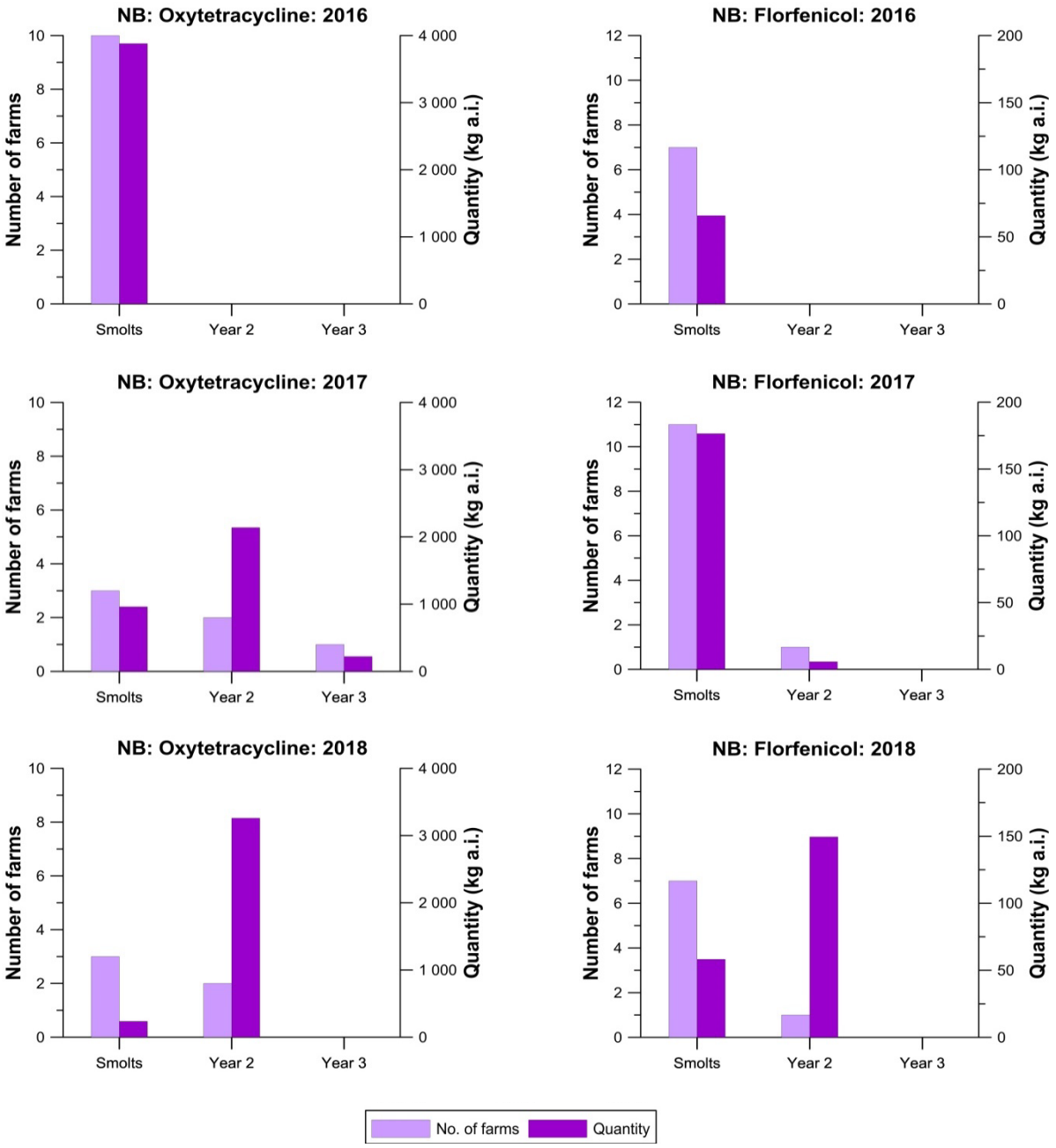

Figure 12. Drug and pesticide use at NB marine finfish farms, per year-class, 2016-2018: antibiotic drugs – oxytetracycline (left) and florfenicol (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Smolts are Atlantic salmon that have been ≤12 months in seawater (since transfer from freshwater hatcheries). 'Year 2' represents Atlantic salmon that have been in seawater 13-24 months and 'Year 3' represents Atlantic salmon that have been in seawater >24 months. Graphs are not shown for erythromycin (1 farm in 2016, 0 farms in 2017 and 2018), ormetoprim (0 farms in 2016-2018), and trimethoprim (3 farms in 2016, 2 farms in 2017, 1 farm in 2018). Also not shown are data for a non-commercial site on Grand Manan Island (wild salmon project). Data sources: NAPRD (DFO 2020b); G.H. Cline & R.W. MacDougall (DFO, St. George, NB, pers. comm.).

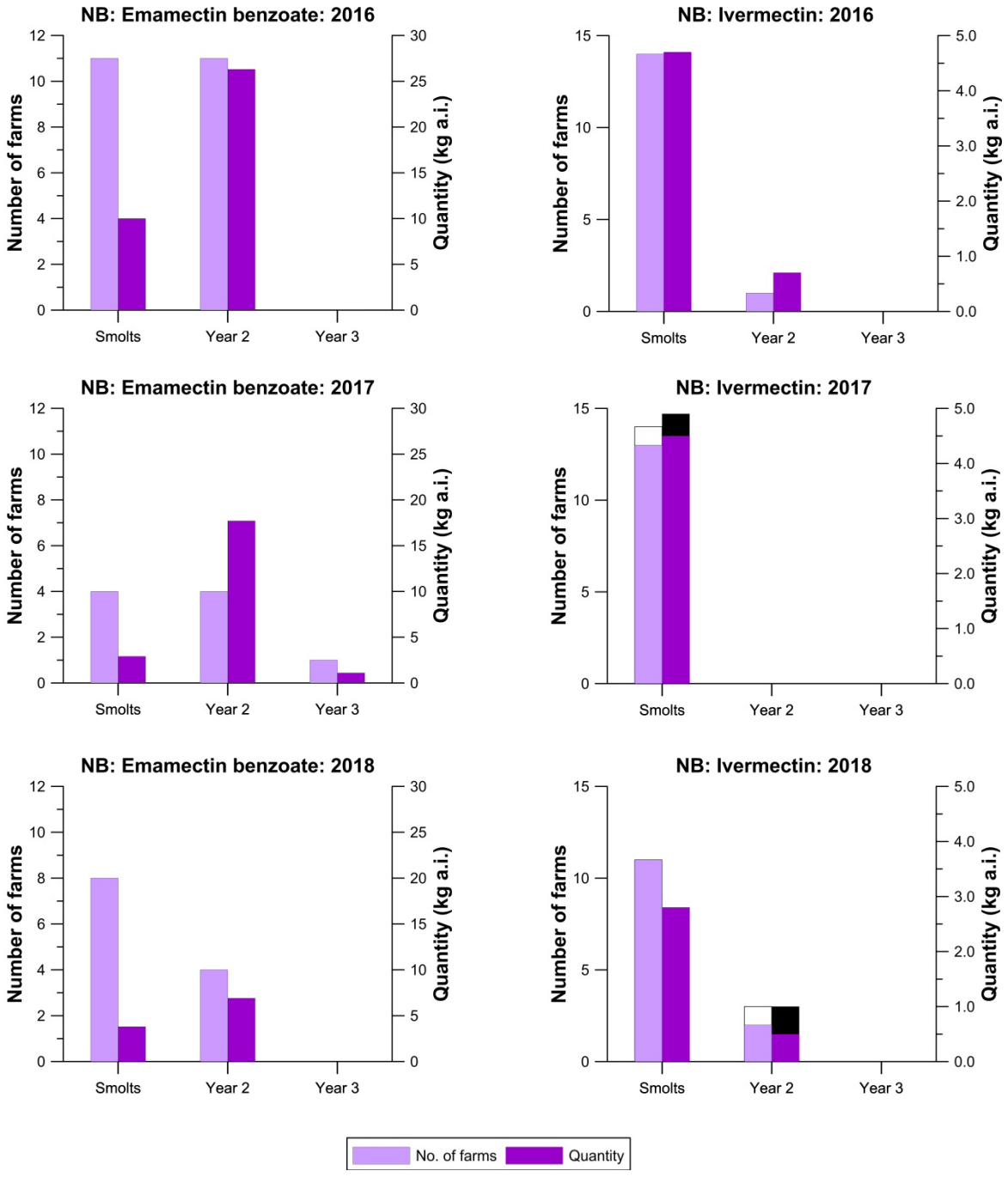

Figure 12. (cont'd). Drug and pesticide use at NB marine finfish farms, per year-class, 2016-2018: pest control drugs – emamectin benzoate (left) and ivermectin (right). White and black bars in the ivermectin graphs for 2017 and 2018 represent selamectin trials (smolts at one farm in 2017; 'year 2' salmon at one farm in 2018).

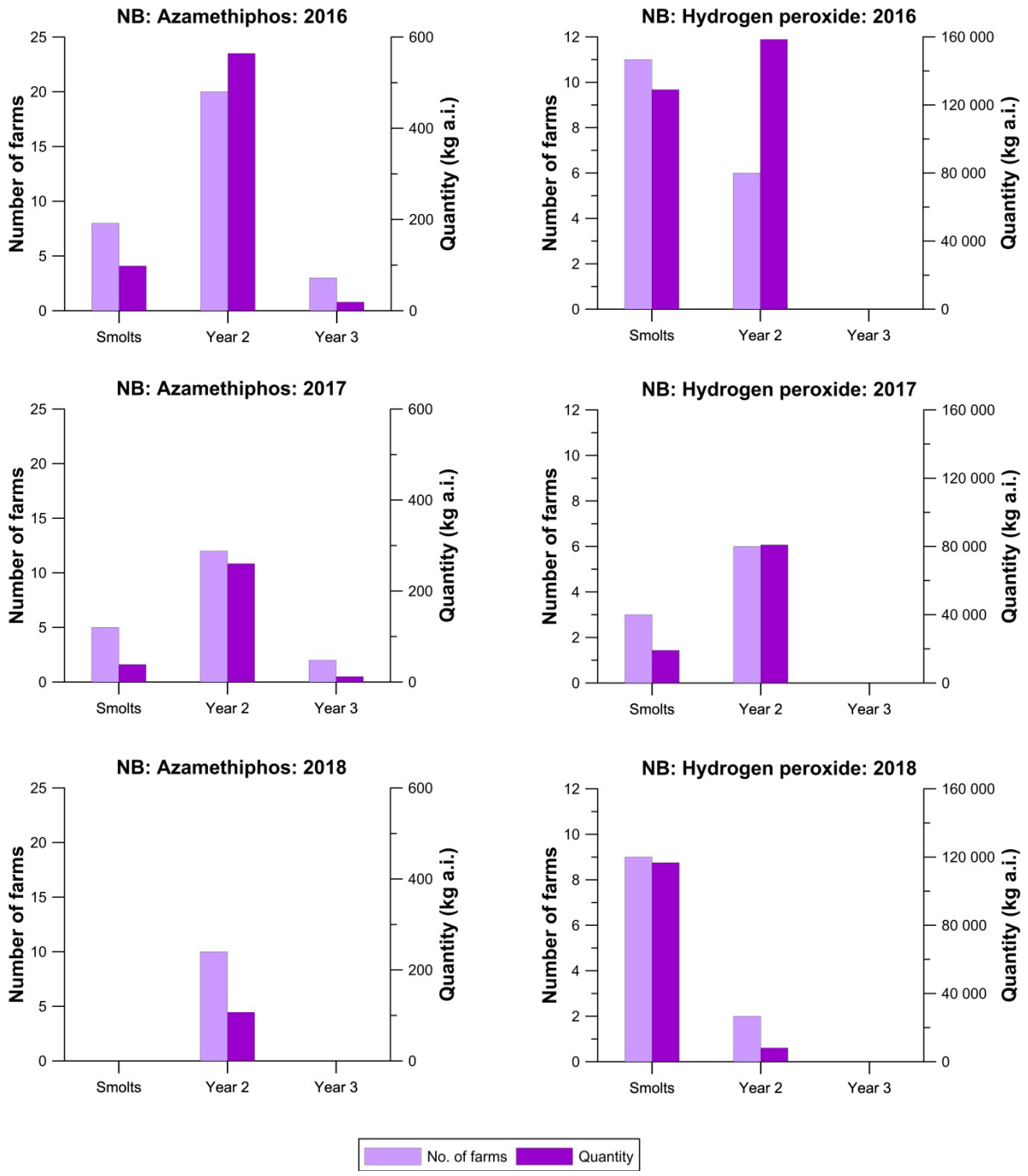

Figure 12. (concluded). Drug and pesticide use at NB marine finfish farms, per year-class, 2016-2018: pesticides – azamethiphos (left) and hydrogen peroxide (right).

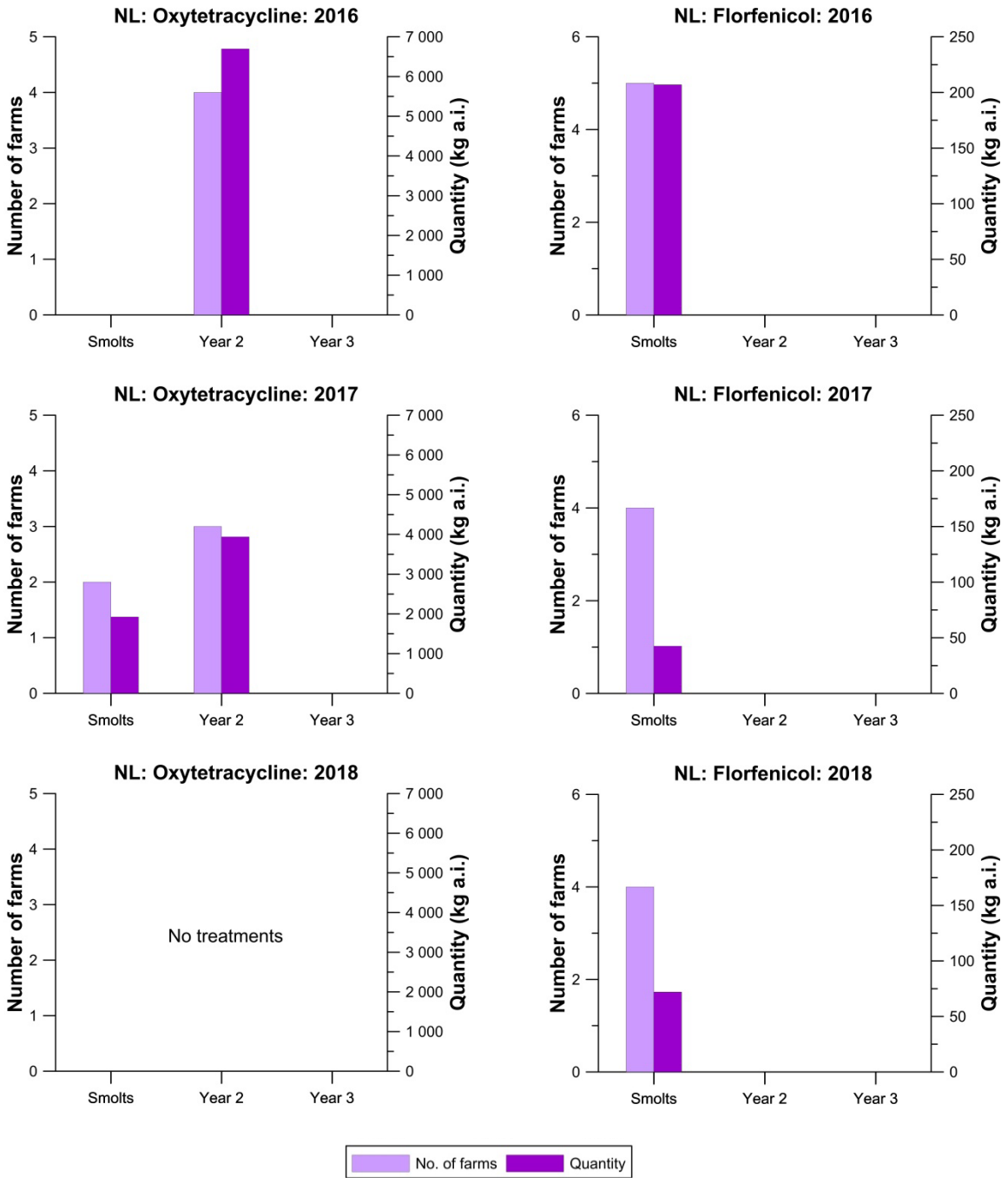

Figure 13. Drug and pesticide use at NL marine finfish farms, per year-class, 2016-2018: antibiotic drugs – oxytetracycline (left) and florfenicol (right). The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Smolts are Atlantic salmon that have been ≤12 months in seawater (since transfer from freshwater hatcheries). 'Year 2' represents Atlantic salmon that have been in seawater 13-24 months and 'Year 3' represents Atlantic salmon that have been in seawater >24 months. Graphs are not shown for erythromycin (1 farm in 2016; 0 farms in 2017 and 2018), ormetoprim (0 farms in 2016-2018), and trimethoprim (2 farms in 2016; 0 farms in 2017 and 2018). Data sources: NAPRD (DFO 2020b); C. Hendry (DFO, St John's, NL, pers. comm.).

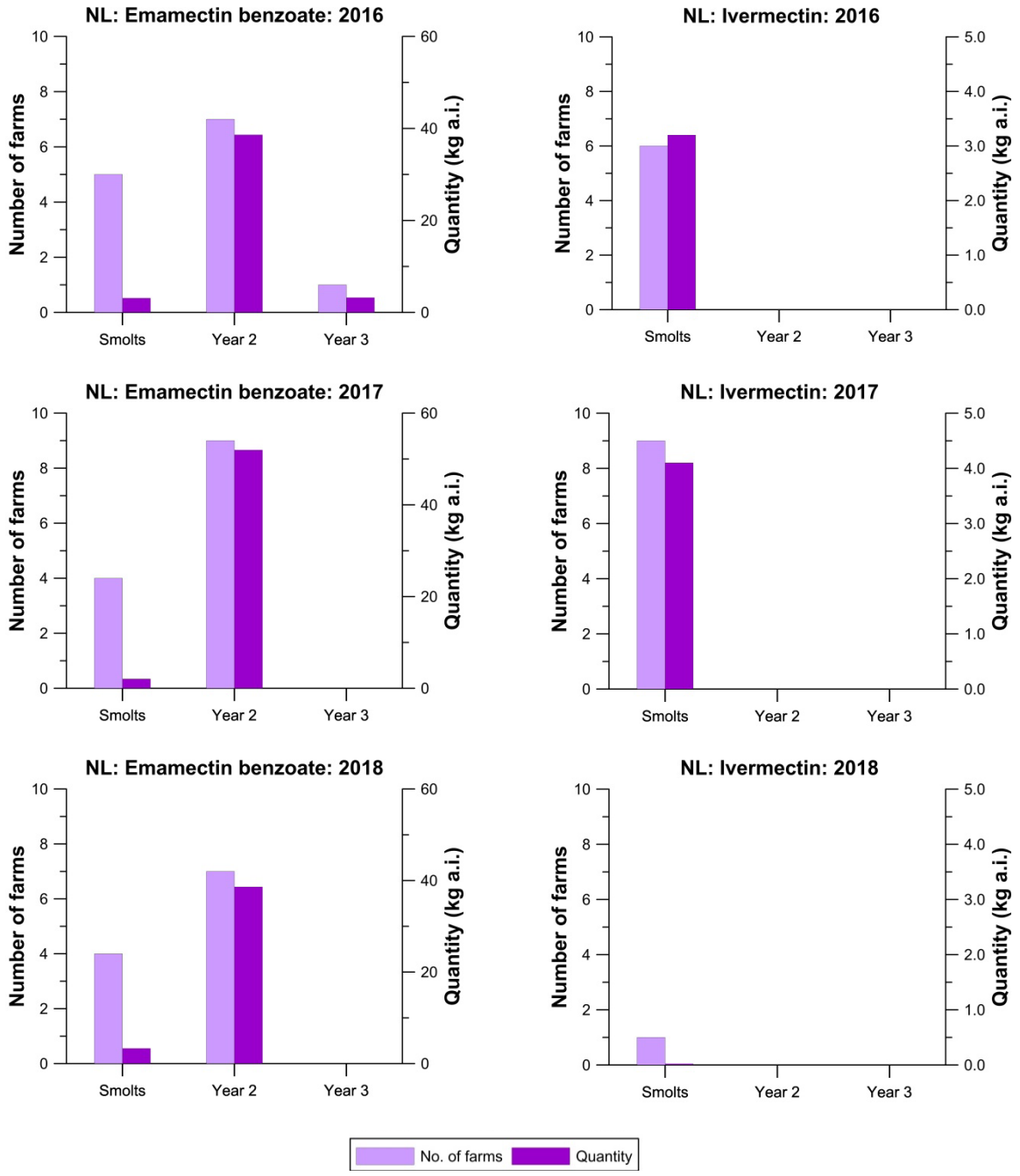

Figure 13. (cont'd). Drug and pesticide use at NL marine finfish farms, per year-class, 2016-2018: pest control drugs – emamectin benzoate (left) and ivermectin (right). Not included is one steelhead farm in the inner Bay d'Espoir area, which used 0.1 kg of emamectin benzoate in 2016.

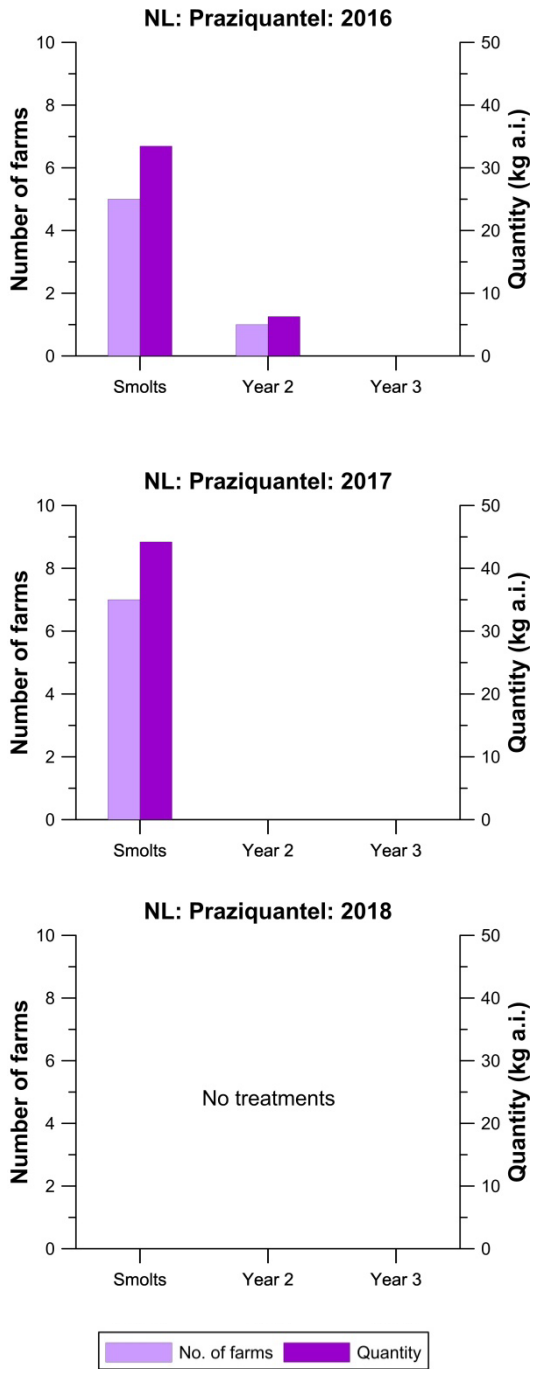

Figure 13 (cont'd). Drug and pesticide use at NL marine finfish farms, per year-class, 2016-2018: pest control drugs – praziquantel.

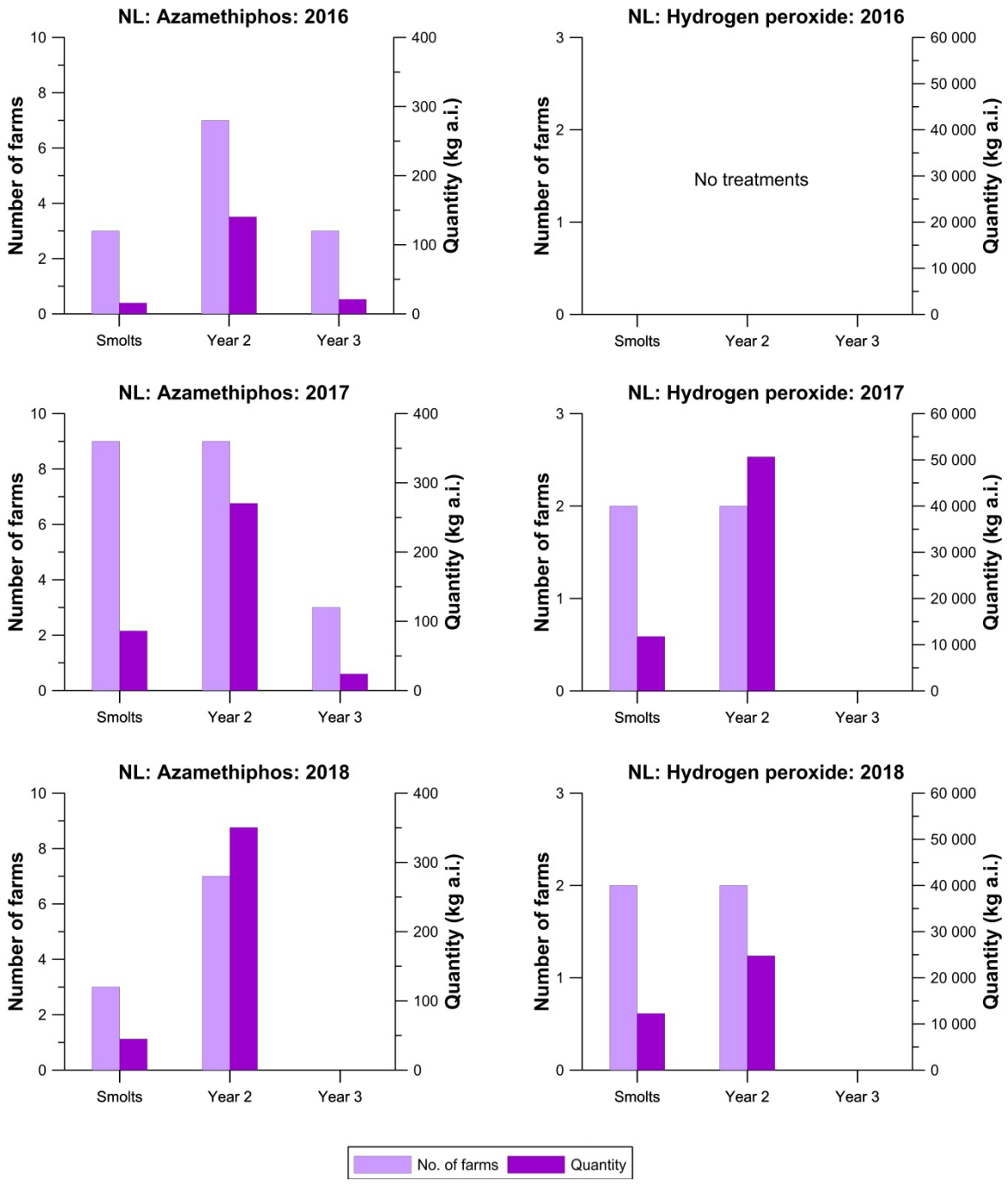

Figure 13. (concluded). Drug and pesticide use at NL marine finfish farms, per year-class, 2016-2018: pesticides – azamethiphos (left) and hydrogen peroxide (right).

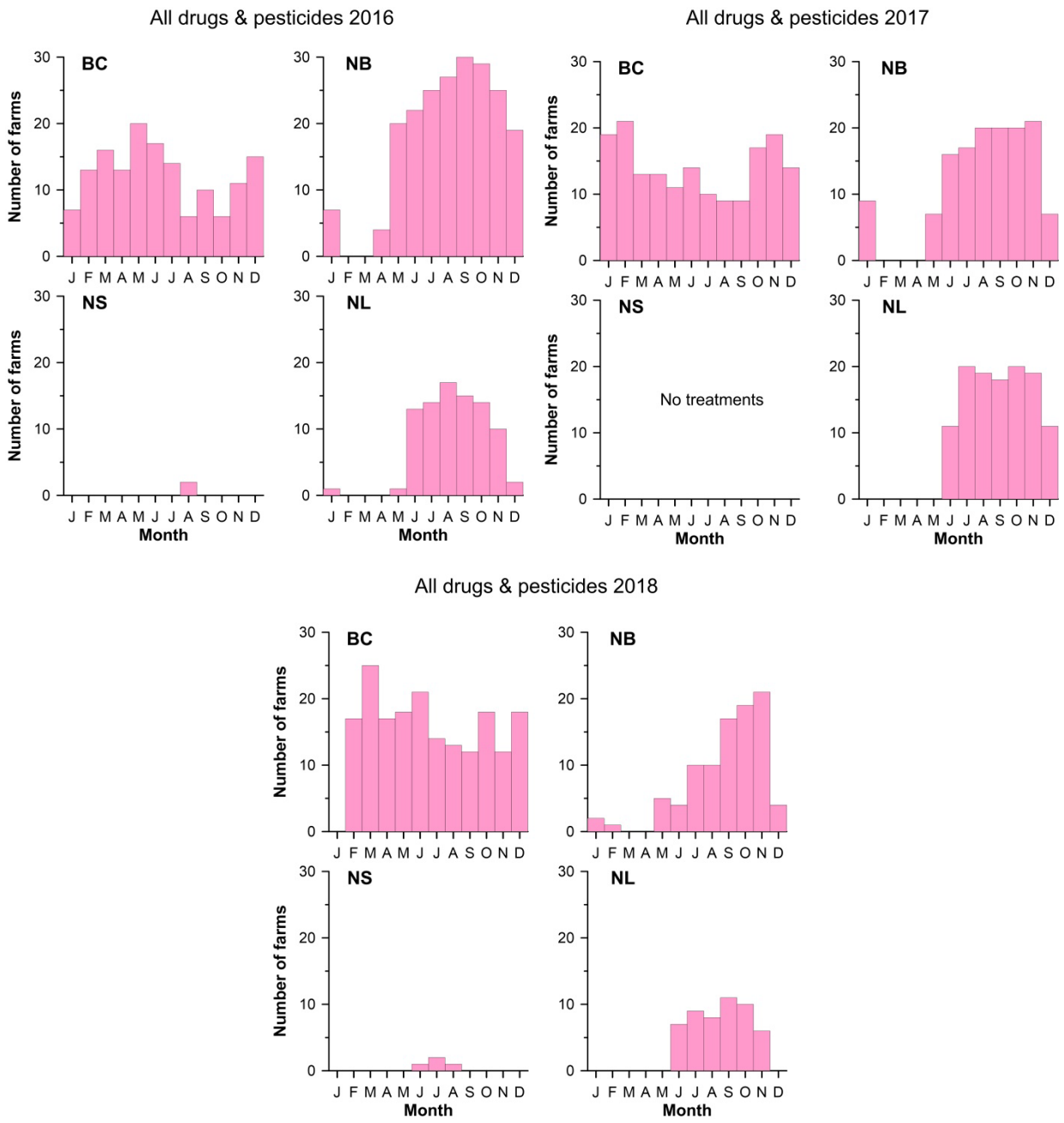

Figure 14. Number of farms treated with drugs and pesticides per month, by province, 2016-2018. Values are based on the start and end dates of treatment entries in the Aquaculture Integrated Information System (AQUIIS); except 56% of BC treatment entries in 2016 did not include treatment end dates.

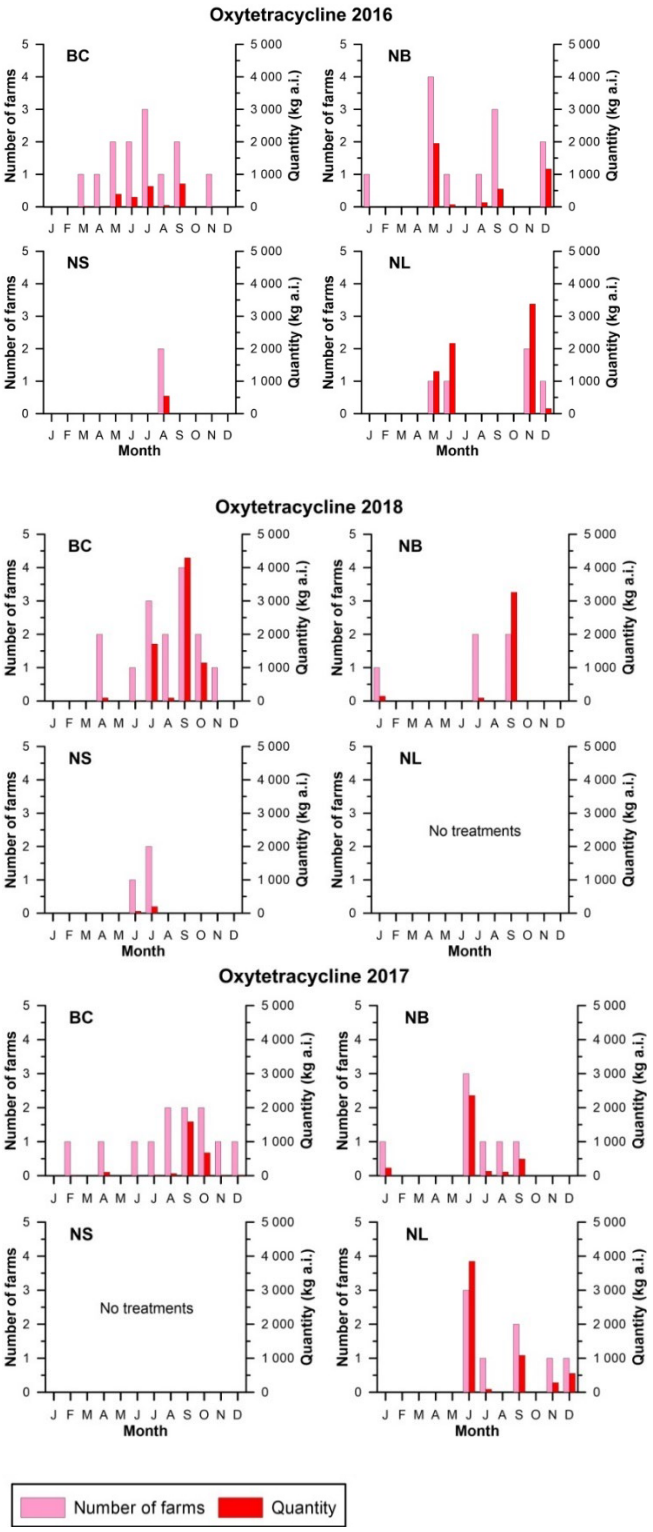

Figure 15a. Drug and pesticide use at Canadian marine finfish farms per month, by province, 2016-2018: oxytetracycline. The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used, based on the month of the start date of each treatment entry in the Aquaculture Integrated Information System (AQUIIS).

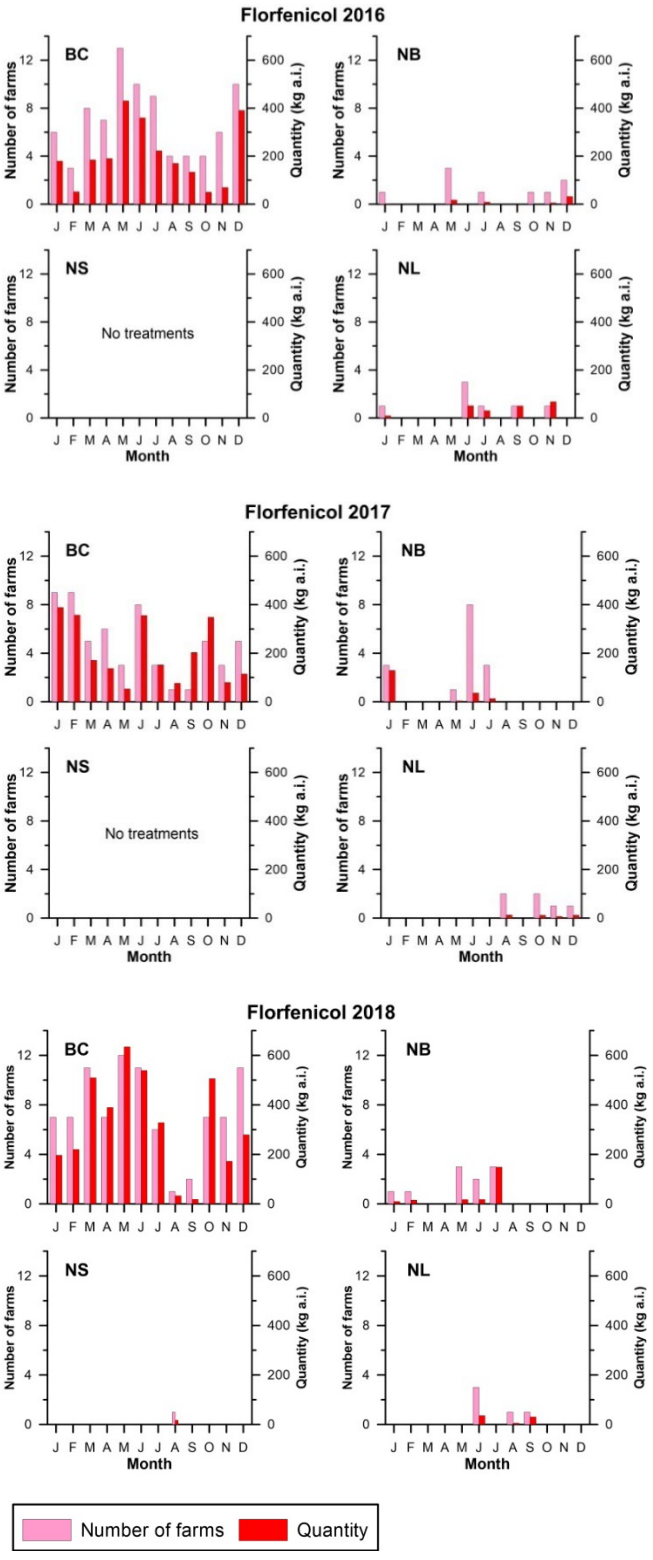

Figure 15b. Drug and pesticide use at Canadian marine finfish farms per month, by province, 2016-2018: florfenicol

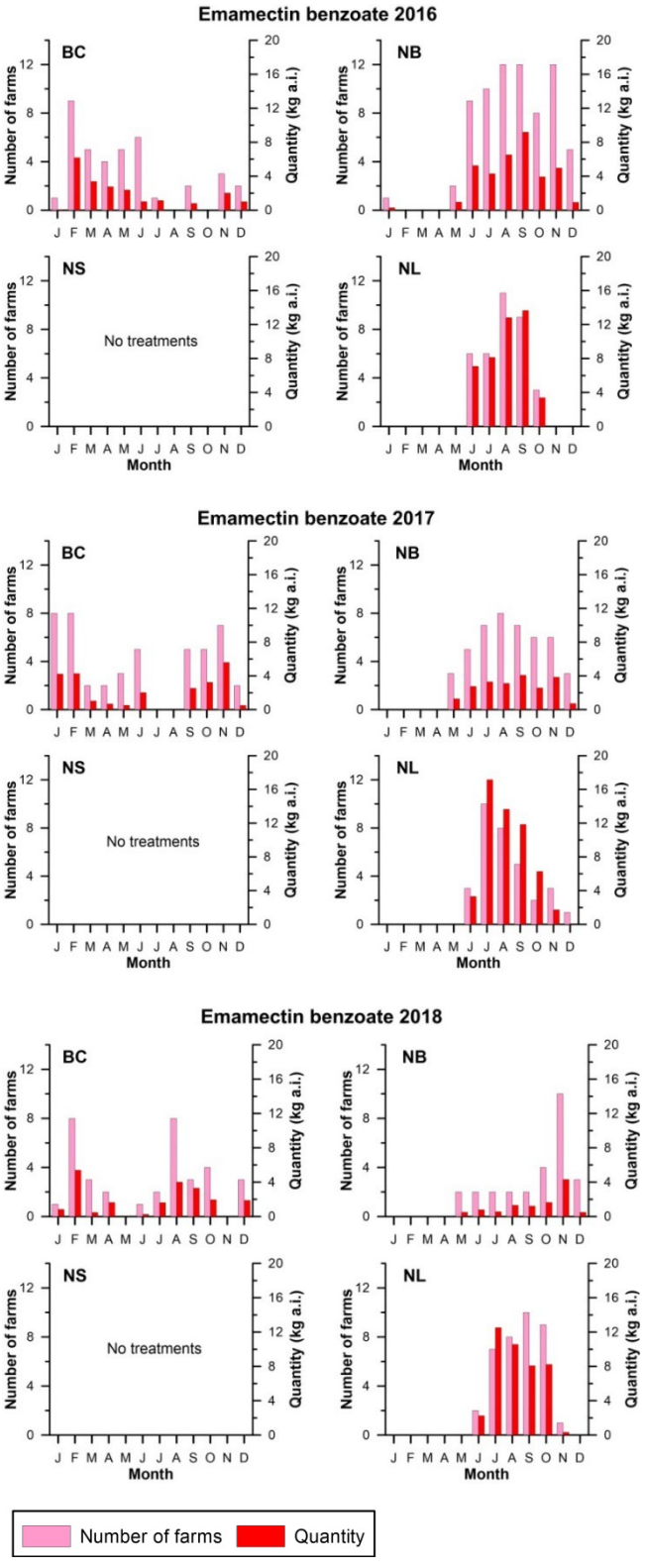

Figure 15c. Drug and pesticide use at Canadian marine finfish farms per month, by province, 2016-2018: emamectin benzoate.

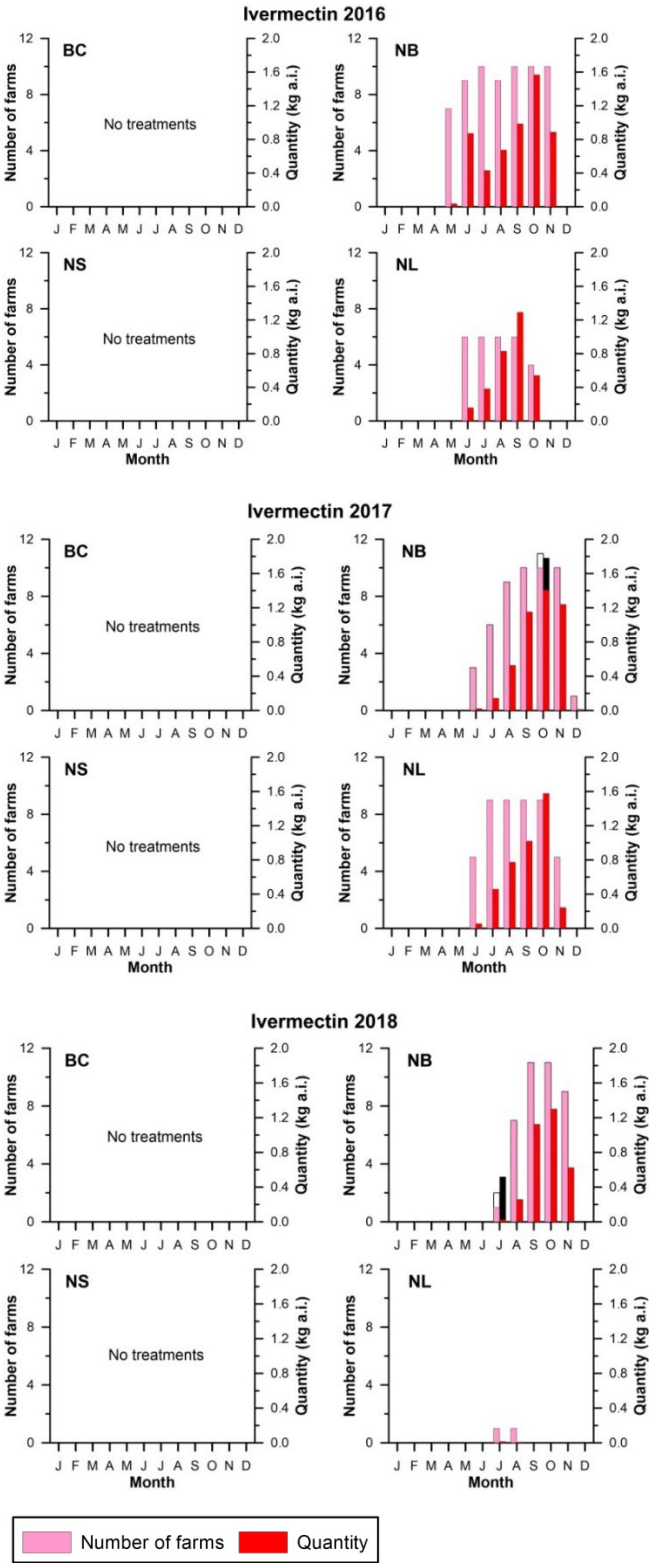

Figure 15d. Drug and pesticide use at Canadian marine finfish farms per month, by province, 2016-2018: ivermectin. The white and black bars in the NB graphs for 2017 and 2018 represent selamectin trials (one farm in October 2017 and one farm in July 2018; both trials 1-week duration).

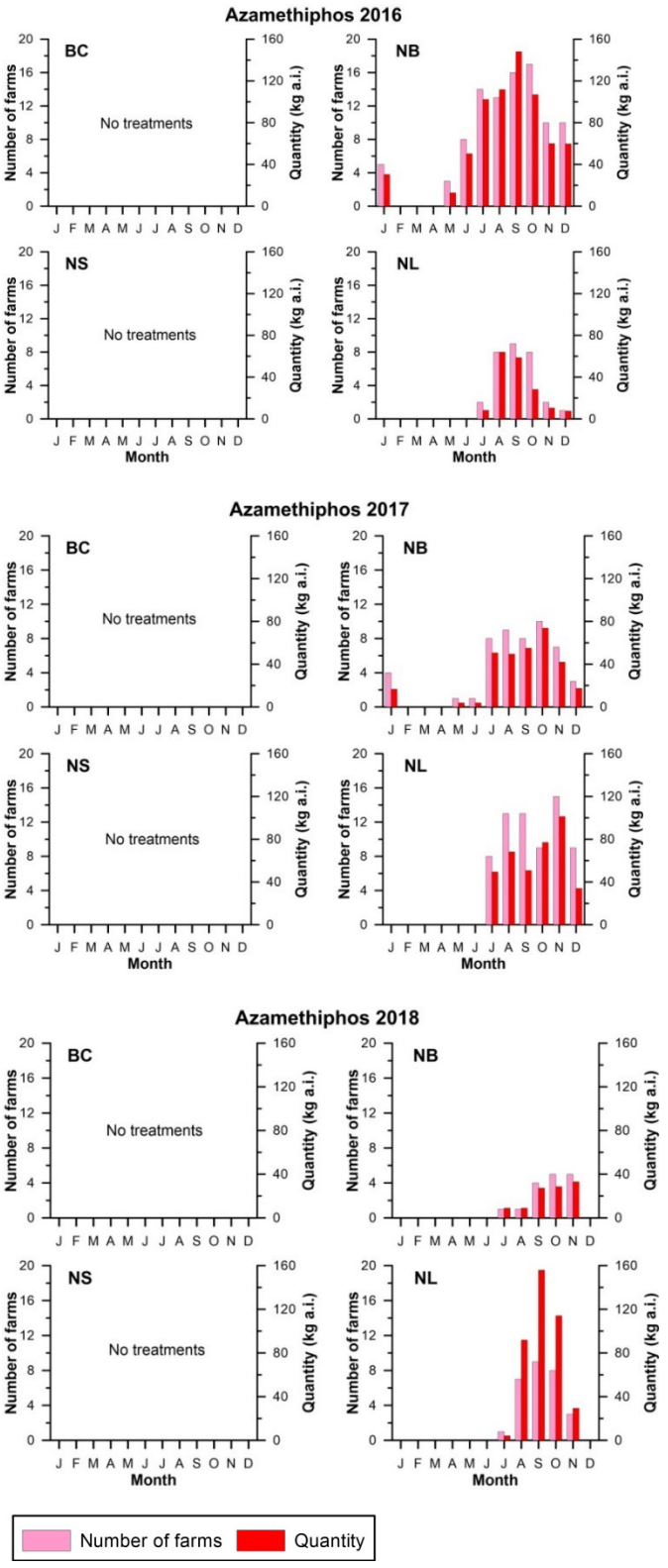

Figure 15e. Drug and pesticide use at Canadian marine finfish farms per month, by province, 2016-2018: azamethiphos.

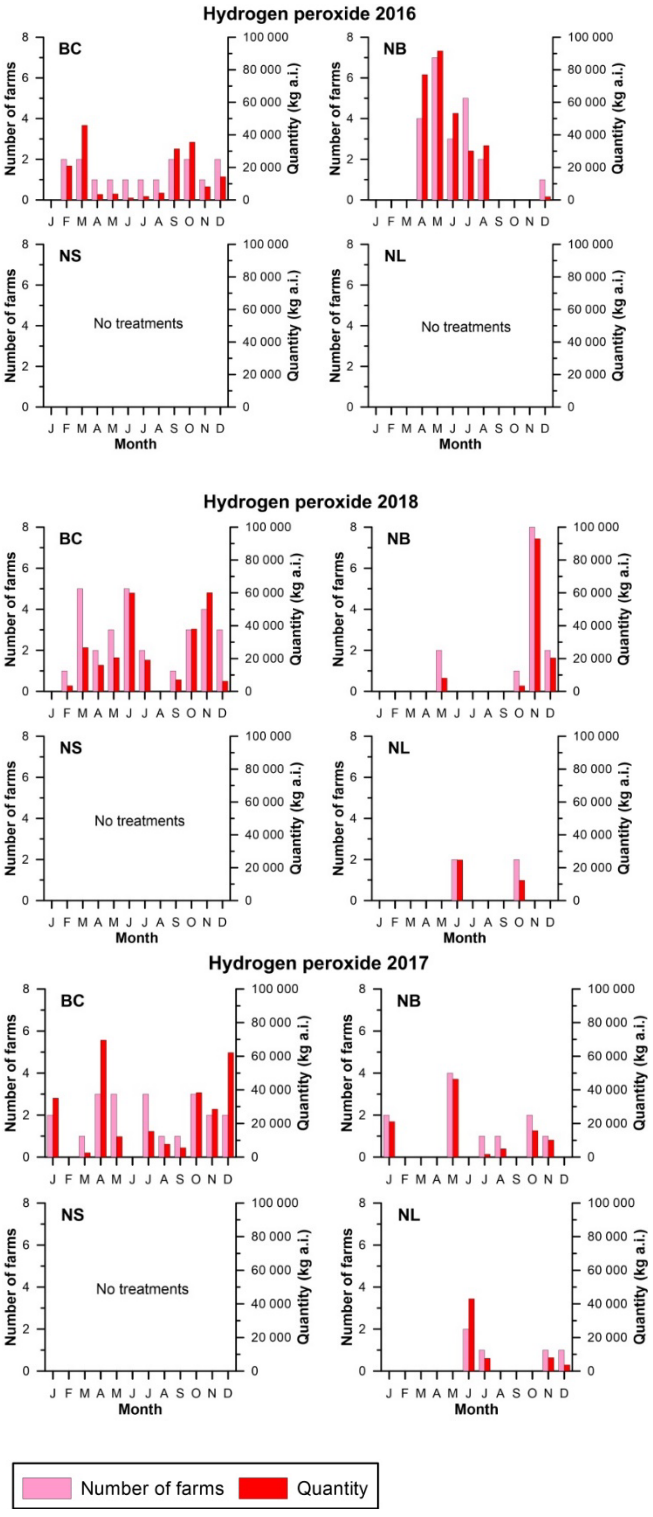

Figure 15f. Drug and pesticide use at Canadian marine finfish farms per month, by province, 2016-2018: hydrogen peroxide.

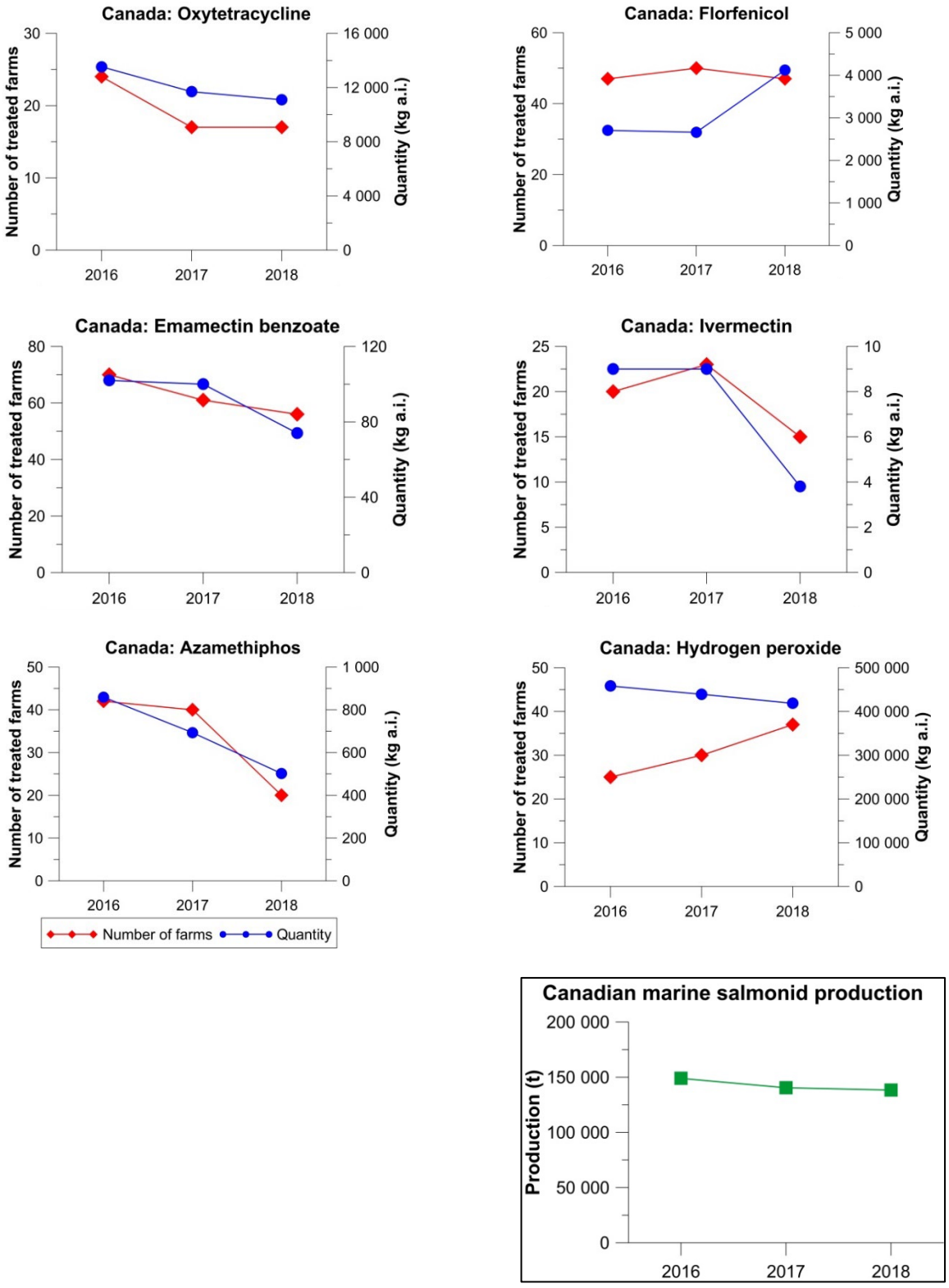

Figure 16. Inter-year comparisons of drug and pesticide use at Canadian marine finfish farms, 2016-2018: all Canada. The graphs show the number of farms treated and the quantity of active ingredient (a.i.) used. Ivermectin data include selamectin trials (NB). Data source: NAPRD (DFO 2020b). Also shown is Canadian marine salmonid production in the same years (see Table 2).

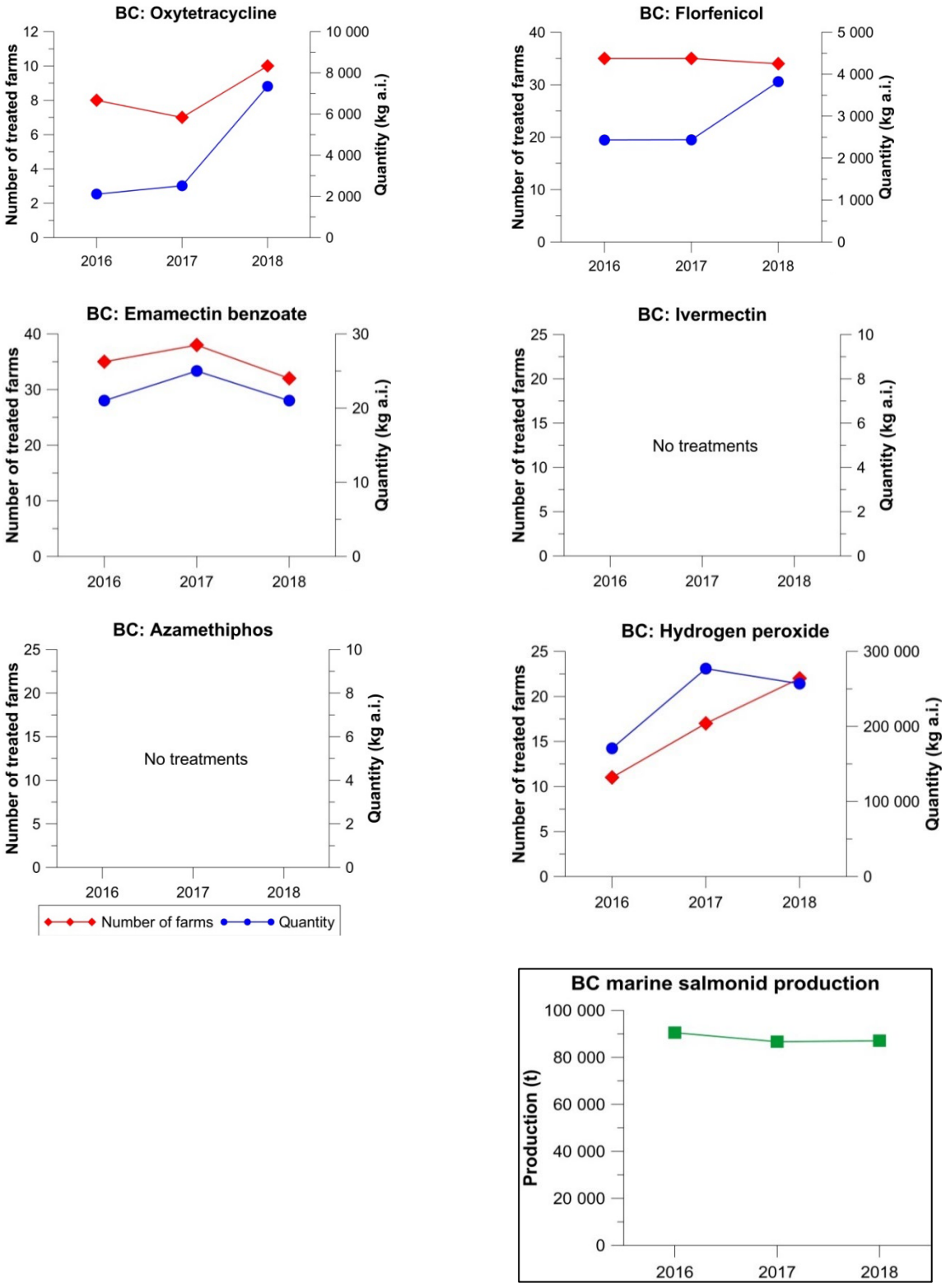

Figure 16b. Inter-year comparisons of drug and pesticide use at Canadian marine finfish farms, 2016-2018: British Columbia (BC). Also shown is BC marine salmonid production in the same years.

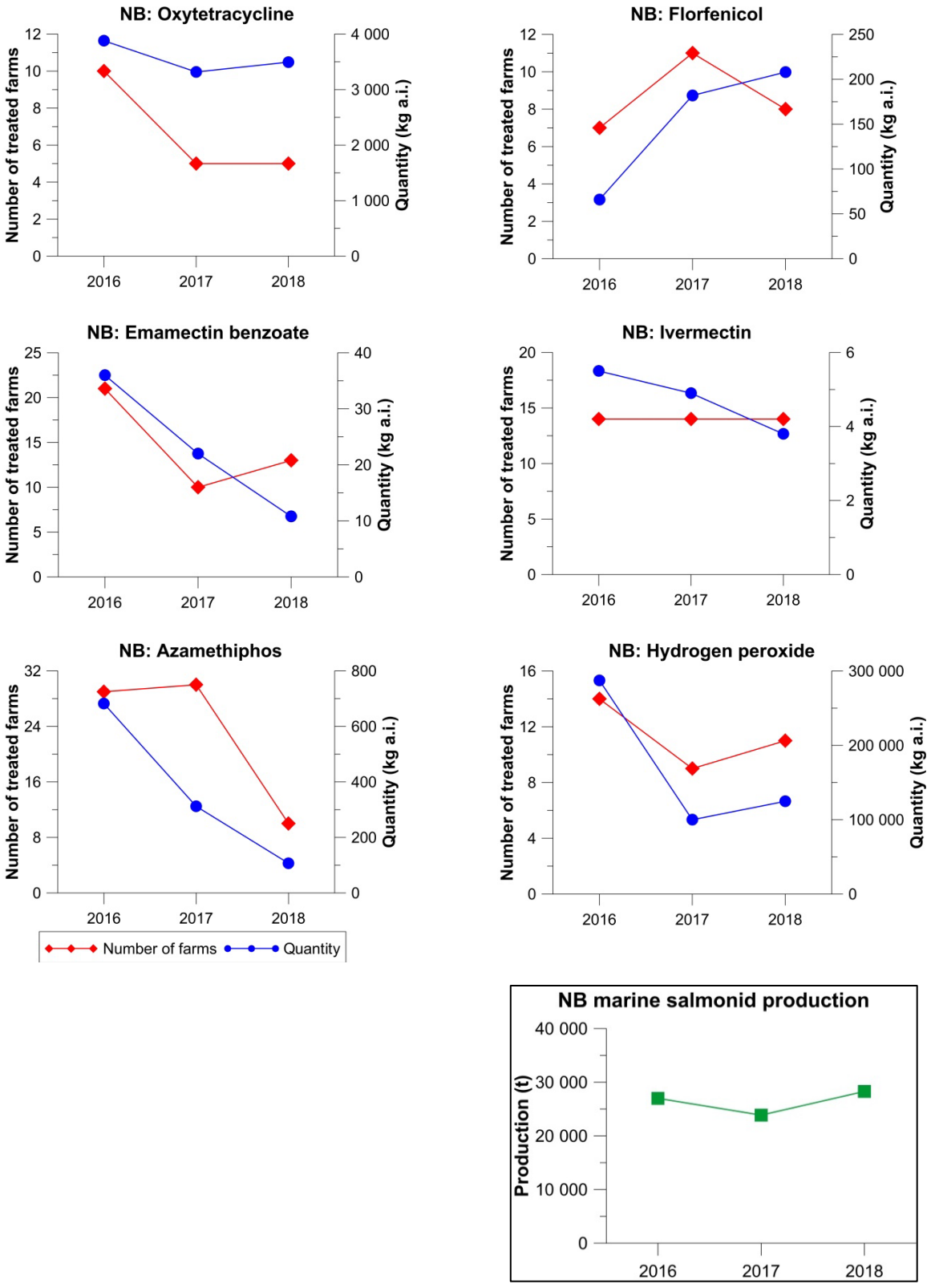

Figure 16c. Inter-year comparisons of drug and pesticide use at Canadian marine finfish farms, 2016-2018: New Brunswick (NB). Ivermectin data include selamectin trials in NB (1 farm, 0.38 kg in 2017; 1 farm, 0.49 kg in 2018). Also shown is NB marine salmonid production in the same years.

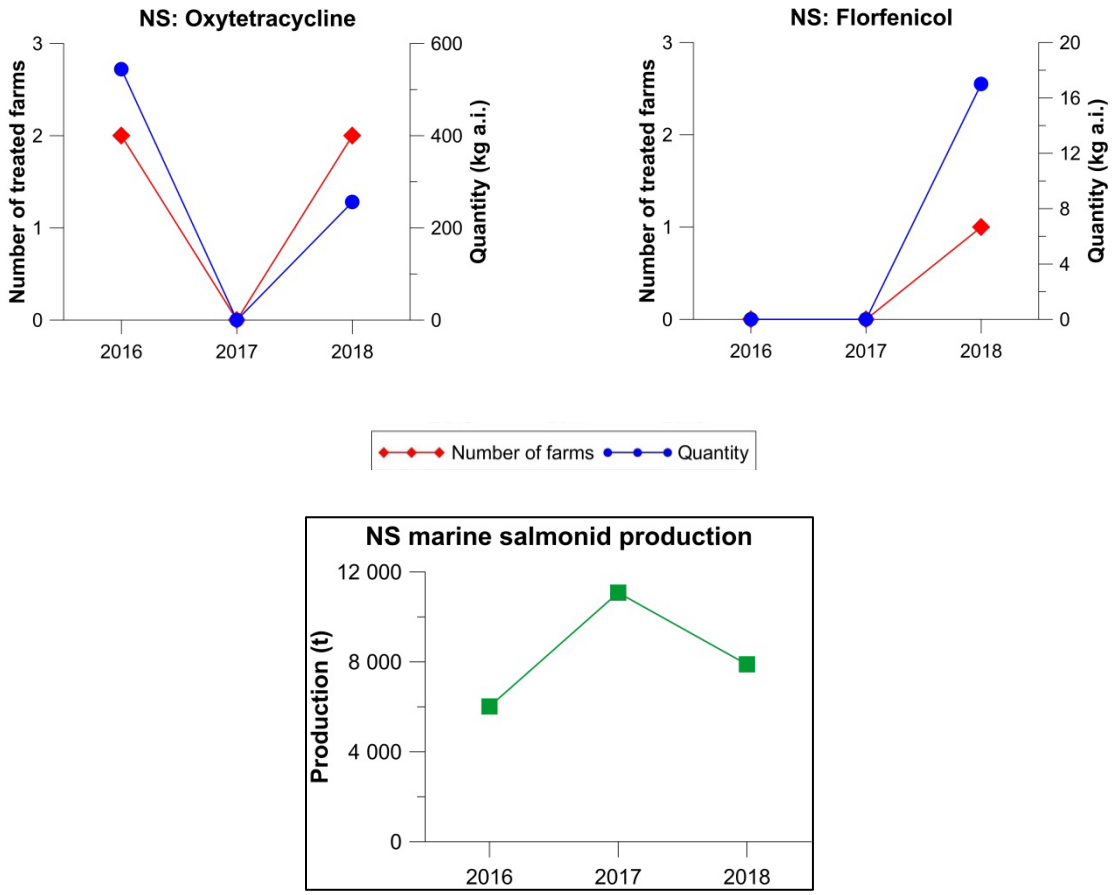

Figure 16d. Inter-year comparisons of drug and pesticide use at Canadian marine finfish farms, 2016-2018: Nova Scotia (NS). Also shown is NS marine salmonid production in the same years. No pest control drugs or pesticides were used in NS during these years.

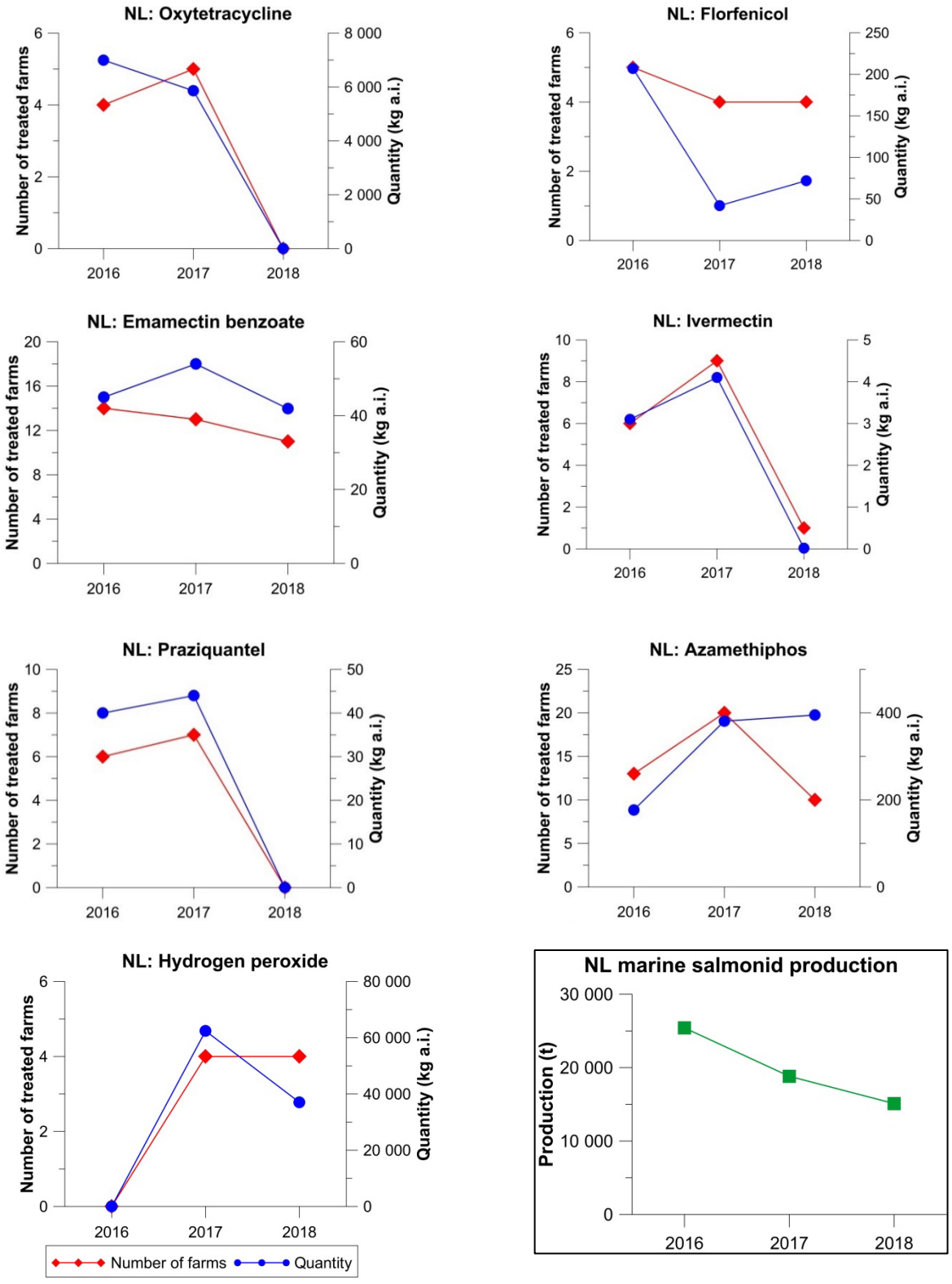

Figure 16e. Inter-year comparisons of number of drug and pesticide use at Canadian marine finfish farms, 2016-2018: Newfoundland & Labrador (NL). Also shown is NL marine salmonid production in the same years.

APPENDIX A.

Table A1a. Annual usage of antibiotic drugs at Canadian marine finfish farms, per province, 2016. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2016	Canada	BC	NB	NS	NL
All antibiotic drugs					
Number of reporting farms	152	78	44	8	22
Number of farms treated	67	41	14	2	10
Oxytetracycline					
Number of farms treated	24	8	10	2	4
Total quantity used (kg a.i.)	13 529	2 108	3 881	544	6 997
Max. quantity used per farm (kg a.i.)	2 164	621	1 360	297	2 164
Florfenicol					
Number of farms treated	47	35	7	0	5
Total quantity used (kg a.i.)	2 705	2 432	66	0	207
Max. quantity used per farm (kg a.i.)	422	422	19	0	82
Erythromycin					
Number of farms treated	2	0	1	0	1
Total quantity used (kg a.i.)	232	0	80	0	153
Max. quantity used per farm (kg a.i.)	153	0	80	0	153
Ormetoprim/Sulfadimethoxine					
Number of farms treated	3	3	0	0	0
Total quantity used (kg a.i.)	112	112	0	0	0
Max. quantity used per farm (kg a.i.)	53	53	0	0	0
Trimethoprim/Sulfadiazine					
Number of farms treated	5	0	3	0	2
Total quantity used (kg a.i.)	224	0	50	0	174
Max. quantity used per farm (kg a.i.)	94	0	33	0	94

Table A1b. Annual usage of antibiotic drugs at Canadian marine finfish farms, per province, 2017. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2017	Canada	BC	NB	NS	NL
All antibiotic drugs					
Number of reporting farms	162	81	45	11	25
Number of farms treated	66	40	17	0	9
Oxytetracycline					
Number of farms treated	17	7	5	0	5
Total quantity used (kg a.i.)	11 693	2 514	3 318	0	5 860
Max. quantity used per farm (kg a.i.)	1 503	1 503	1 192	0	1 425
Florfenicol					
Number of farms treated	50	35	11	0	4
Total quantity used (kg a.i.)	2 661	2 436	182	0	42
Max. quantity used per farm (kg a.i.)	319	319	112	0	19
Erythromycin					
Number of farms treated	0	0	0	0	0
Total quantity used (kg a.i.)	0	0	0	0	0
Ormetoprim/Sulfadimethoxine					
Number of farms treated	0	0	0	0	0
Total quantity used (kg a.i.)	0	0	0	0	0
Trimethoprim/Sulfadiazine					
Number of farms treated	2	0	2	0	0
Total quantity used (kg a.i.)	34	0	34	0	0
Max. quantity used per farm (kg a.i.)	18	0	18	0	0

Table A1c. Annual usage of antibiotic drugs at Canadian marine finfish farms, per province, 2018. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2018	Canada	BC	NB	NS	NL
All antibiotic drugs					
Number of reporting farms	136	73	36	8	19
Number of farms treated	59	40	12	3	4
Oxytetracycline					
Number of farms treated	17	10	5	2	0
Total quantity used (kg a.i.)	11 097	7 347	3 495	256	0
Max. quantity used per farm (kg a.i.)	1 761	1 691	1 761	171	0
Florfenicol					
Number of farms treated	47	34	8	1	4
Total quantity used (kg a.i.)	4 121	3 824	208	17	72
Max. quantity used per farm (kg a.i.)	404	404	150	17	41
Erythromycin					
Number of farms treated	1	1	0	0	0
Total quantity used (kg a.i.)	1	1	0	0	0
Max. quantity used per farm (kg a.i.)	1	1	0	0	0
Ormetoprim/Sulfadimethoxine					
Number of farms treated	2	2	0	0	0
Total quantity used (kg a.i.)	<1	<1	0	0	0
Max. quantity used per farm (kg a.i.)	<1	<1	0	0	0
Trimethoprim/Sulfadiazine					
Number of farms treated	1	0	1	0	0
Total quantity used (kg a.i.)	28	0	28	0	0
Max. quantity used per farm (kg a.i.)	28	0	28	0	0

Table A2a. Annual usage of pest control drugs at Canadian marine finfish farms, per province, 2016. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2016	Canada	BC	NB	NS	NL
All pest control drugs					
Number of reporting farms	152	78	44	8	22
Number of farms treated	79	35	26	0	18
Emamectin benzoate					
Number of farms treated	70	35	21	0	14
Total quantity used (kg a.i.)	102.3	20.7	36.3	0	45.0
Max. quantity used per farm (kg a.i.)	11.1	1.8	10.7	0	11.1
Ivermectin					
Number of farms treated	20	0	14	0	6
Total quantity used (kg a.i.)	8.6	0	5.5	0	3.1
Max. quantity used per farm (kg a.i.)	1.2	0	1.2	0	0.8
Selamectin					
Number of farms treated	0	0	0	0	0
Total quantity used (kg a.i.)	0	0	0	0	0
Max. quantity used per farm (kg a.i.)	0	0	0	0	0
Praziquantel					
Number of farms treated	6	0	0	0	6
Total quantity used (kg a.i.)	39.7	0	0	0	39.7
Max. quantity used per farm (kg a.i.)	7.6	0	0	0	7.6

Table A2b. Annual usage of pest control drugs at Canadian marine finfish farms, per province, 2017. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2017	Canada	BC	NB	NS	NL
All pest control drugs					
Number of reporting farms	162	81	45	11	25
Number of farms treated	77	38	20	0	19
Emamectin benzoate					
Number of farms treated	61	38	10	0	13
Total quantity used (kg a.i.)	100.2	24.6	21.6	0	54.0
Max. quantity used per farm (kg a.i.)	13.7	1.5	7.7	0	13.7
Ivermectin					
Number of farms treated	22	0	13	0	9
Total quantity used (kg a.i.)	8.6	0	4.5	0	4.1
Max. quantity used per farm (kg a.i.)	0.7	0	0.7	0	0.6
Selamectin					
Number of farms treated	1	0	1	0	0
Total quantity used (kg a.i.)	0.4	0	0.4	0	0
Max. quantity used per farm (kg a.i.)	0.4	0	0.4	0	0
Praziquantel					
Number of farms treated	7	0	0	0	7
Total quantity used (kg a.i.)	44.2	0	0	0	44.2
Max. quantity used per farm (kg a.i.)	8.0	0	0	0	8.0

Table A2c. Annual usage of pest control drugs at Canadian marine finfish farms, per province, 2018. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2018	Canada	BC	NB	NS	NL
All pest control drugs					
Number of reporting farms	136	73	36	8	19
Number of farms treated	63	32	20	0	11
Emamectin benzoate					
Number of farms treated	56	32	13	0	11
Total quantity used (kg a.i.)	74.0	21.3	10.8	0	41.9
Max. quantity used per farm (kg a.i.)	7.1	1.7	2.9	0	7.1
Ivermectin					
Number of farms treated	14	0	13	0	1
Total quantity used (kg a.i.)	3.3	0	3.3	0	<0.1
Max. quantity used per farm (kg a.i.)	0.5	0	0.5	0	<0.1
Selamectin					
Number of farms treated	1	0	1	0	0
Total quantity used (kg a.i.)	0.5	0	0.5	0	0
Max. quantity used per farm (kg a.i.)	0.5	0	0.5	0	0
Praziquantel					
Number of farms treated	0	0	0	0	0
Total quantity used (kg a.i.)	0	0	0	0	0
Max. quantity used per farm (kg a.i.)	0	0	0	0	0

Table A3a. Annual usage of pesticides at Canadian marine finfish farms, per province, 2016. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2016	Canada	BC	NB	NS	NL
All bath pesticides					
Number of reporting farms	152	78	44	8	22
Number of farms treated	54	11	30	0	13
Azamethiphos					
Number of farms treated	42	0	29	0	13
Total quantity used (kg a.i.)	859	0	682	0	177
Max. quantity used per farm (kg a.i.)	80	0	80	0	30
Hydrogen peroxide					
Number of farms treated	25	11	14	0	0
Total quantity used (kg a.i.)	458 314	170 851	287 463	0	0
Max. quantity used per farm (kg a.i.)	64 560	34 118	64 560	0	0

Table A3b. Annual usage of pesticides at Canadian marine finfish farms, per province, 2017. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2017	Canada	BC	NB	NS	NL
All bath pesticides					
Number of reporting farms	162	81	45	11	25
Number of farms treated	59	17	22	0	20
Azamethiphos					
Number of farms treated	40	0	20	0	20
Total quantity used (kg a.i.)	693	0	312	0	381
Max. quantity used per farm (kg a.i.)	56	0	53	0	56
Hydrogen peroxide					
Number of farms treated	30	17	9	0	4
Total quantity used (kg a.i.)	439 436	277 048	99 975	0	62 413

Treatment period: 2017	Canada	BC	NB	NS	NL
Max. quantity used per farm (kg a.i.)	38 822	38 822	24 390	0	28 560

Table A3c. Annual usage of pesticides at Canadian marine finfish farms, per province, 2018. a.i. = active ingredient. Data source: NAPRD (DFO 2020b).

Treatment period: 2018	Canada	BC	NB	NS	NL
All bath pesticides					
Number of reporting farms	136	73	36	8	19
Number of farms treated	53	22	21	0	10
Azamethiphos					
Number of farms treated	20	0	10	0	10
Total quantity used (kg a.i.)	502	0	107	0	395
Max. quantity used per farm (kg a.i.)	70	0	19	0	70
Hydrogen peroxide					
Number of farms treated	37	22	11	0	4
Total quantity used (kg a.i.)	418 747	256 980	124 740	0	37 027
Max. quantity used per farm (kg a.i.)	25 014	25 014	23 760	0	19 665

Table A4. Annual usage of the sea louse control drug lufeneron at freshwater salmonid hatcheries in Canada, by province, 2016-2018. This drug cannot be used at marine farms, but can be used at freshwater hatcheries, under the authority of a Health Canada Emergency Drug Release. Data were not available on which marine farms were stocked with smolts that had been treated with lufeneron in hatcheries. Data source: NAPRD (DFO 2020b).

	2016		2017		2018	
Province	No. of hatcheries	Quantity (kg a.i.)	No. of hatcheries	Quantity (kg a.i.)	No. of hatcheries	Quantity (kg a.i.)
BC	0	0.00	0	0.00	1	5.02
NB	2	3.16	5	16.31	5	16.94
NS	0	0.00	0	0.00	0	0.00
NL	0	0.00	1	1.29	2	20.18
Totals	**2**	**3.16**	**6**	**17.60**	**8**	**42.14**

APPENDIX B.

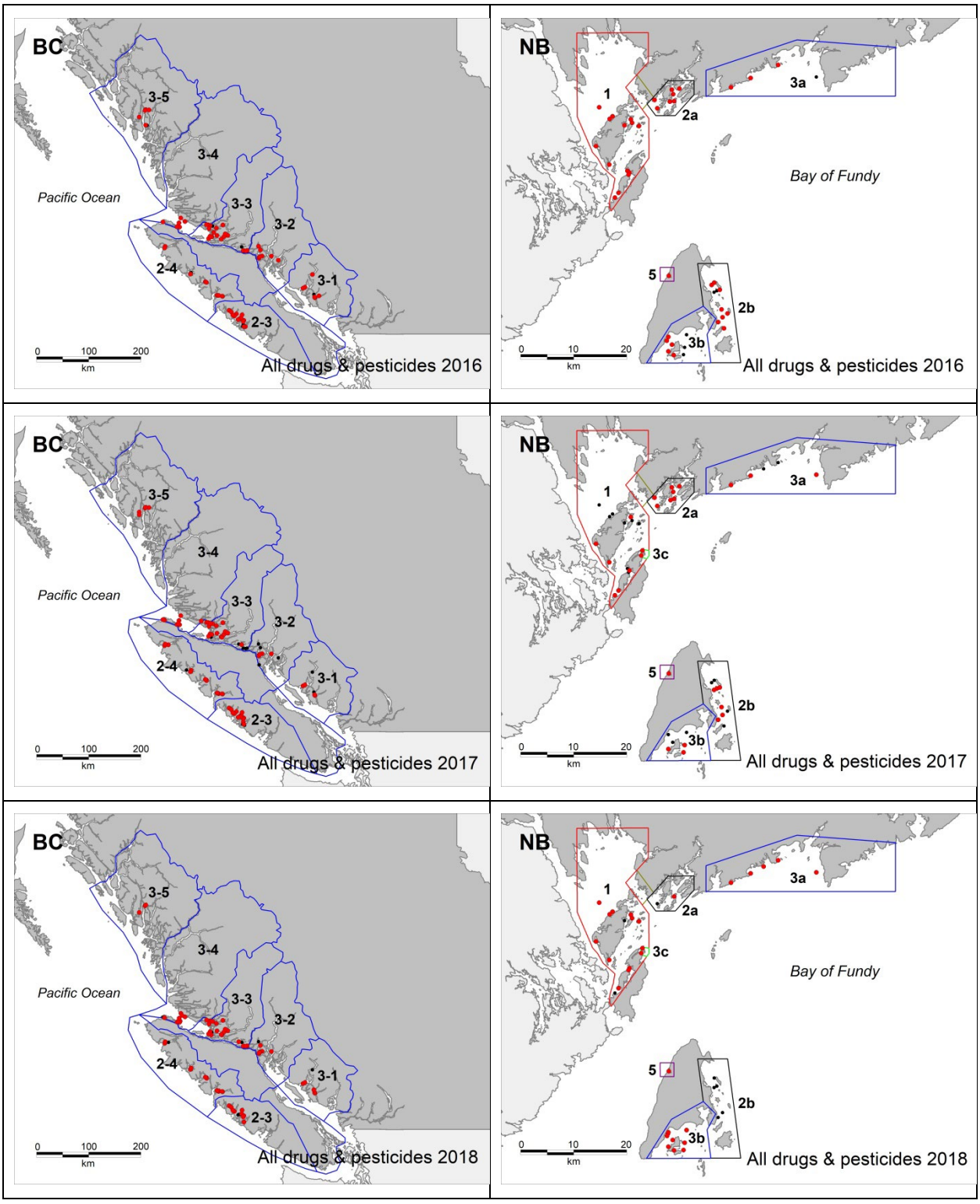

Figure B1. Locations of Canadian marine finfish farms using drugs and pesticides, 2016-2018: BC (left; showing Fish Health Surveillance Zones, FHSZs) and NB (right; showing Bay Management Areas, BMAs). Red symbols (•) are farms that reported using one or more drugs or pesticides; smaller black symbols (•) are untreated farms included in the National Aquaculture Public Reporting Data (NAPRD) in each year (DFO 2020b).

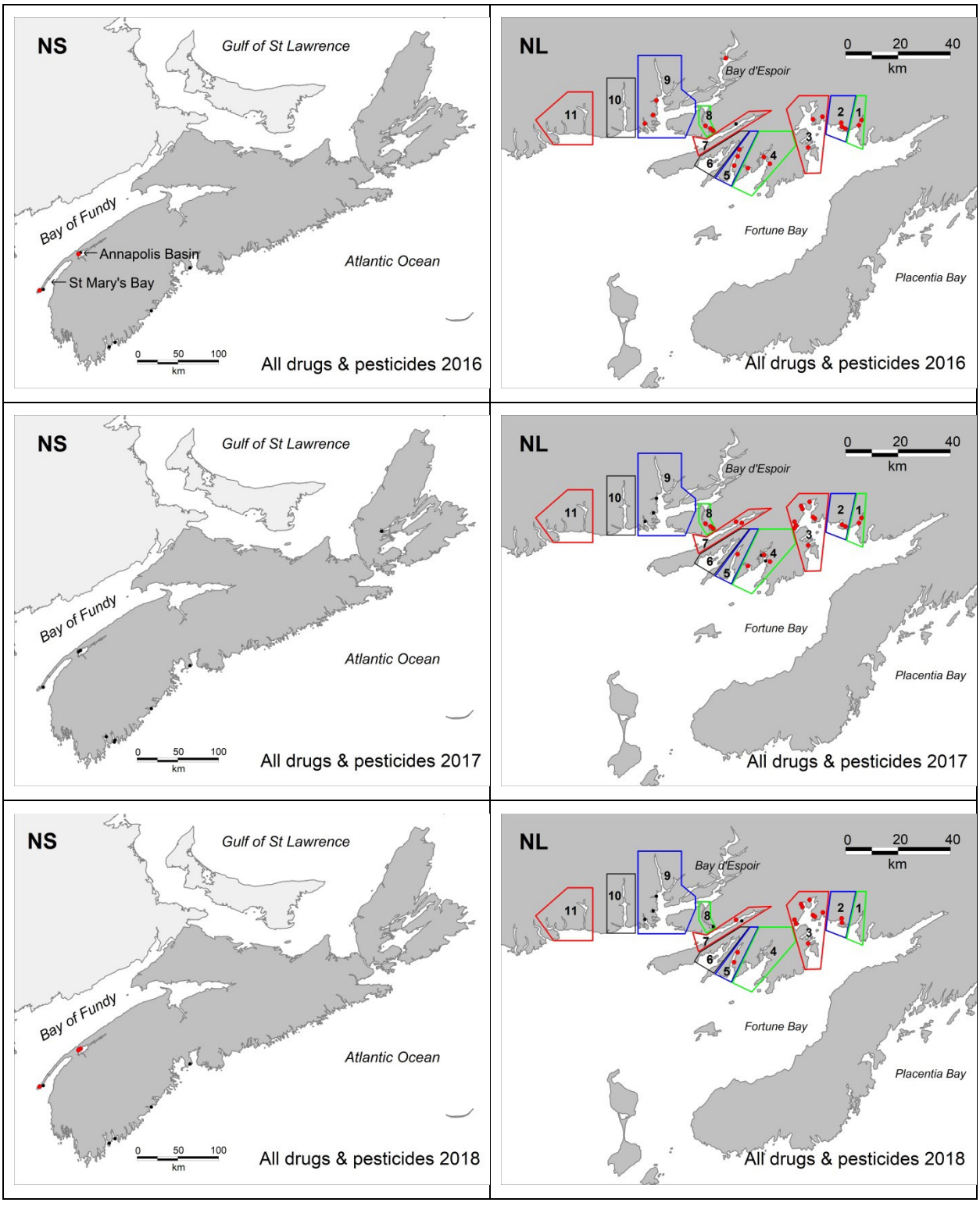

Figure B1 (cont'd). Locations of Canadian marine finfish farms using drugs and pesticides, 2016-2018: NS (left) and NL (right; showing Bay Management Areas, BMAs). Red symbols (•) are farms that reported using one or more drugs or pesticides; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). No drugs or pesticides were used in NS in 2017.

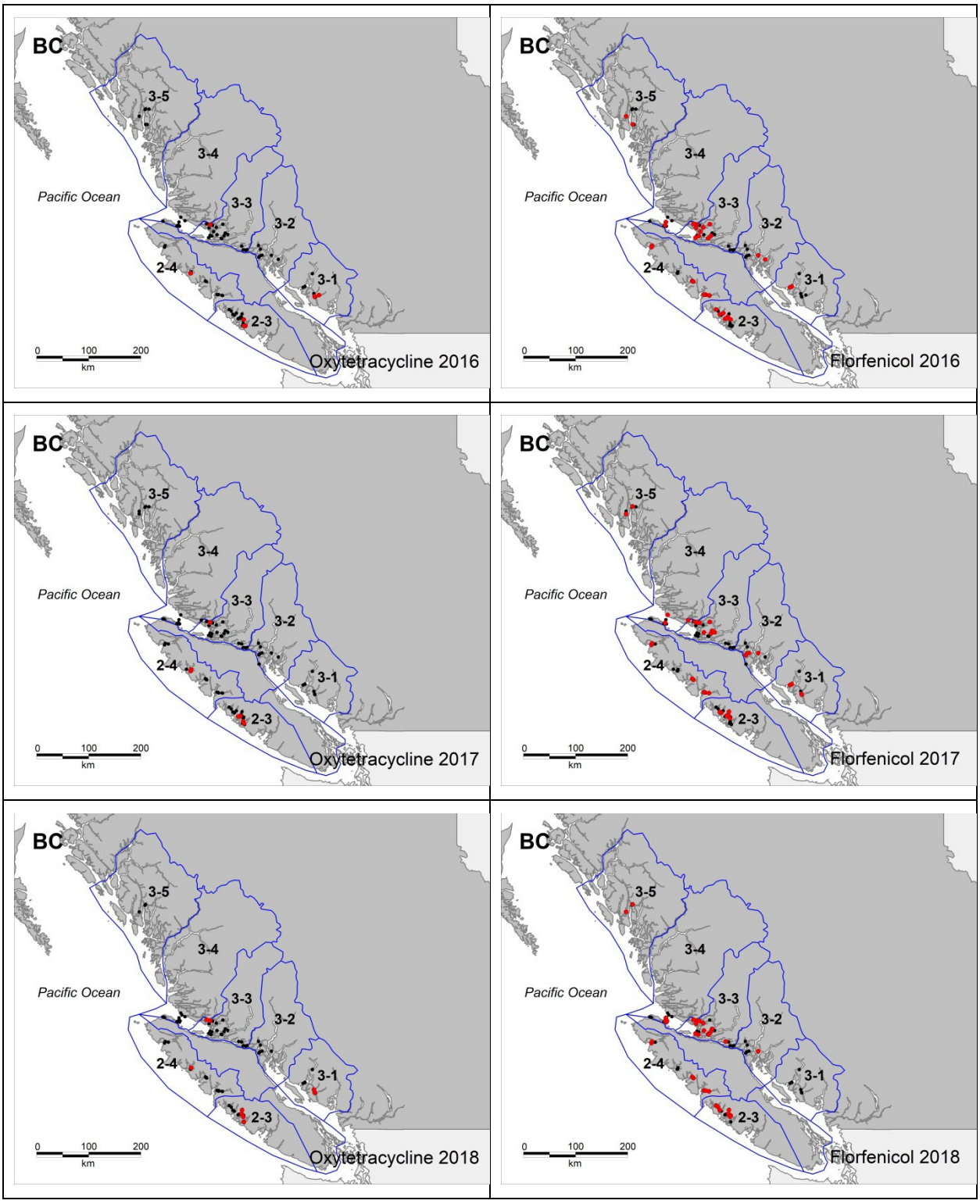

Figure B2. Locations of Canadian marine finfish farms using antibiotic drugs, 2016-2018: BC – oxytetracycline (left) and florfenicol (right). Red symbols (•) are farms that reported using each antibiotic drug; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Maps are not shown for erythromycin (1 farm in FHSZ 3-3 in 2018), ormetoprim (3 farms in FHSZ 2-3 in 2016; 2 farms in FHSZ 2-4 in 2018), and trimethoprim (no farms).

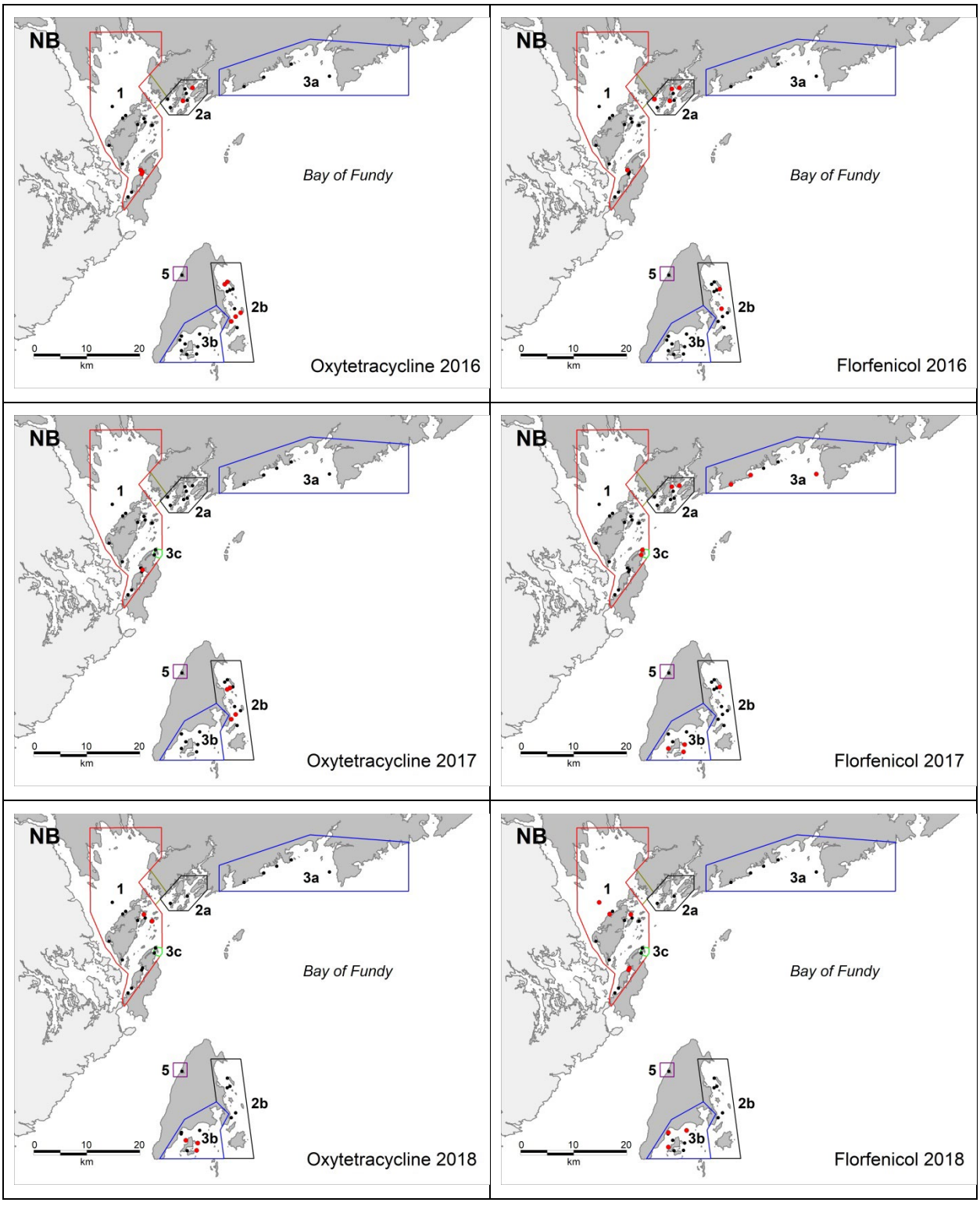

Figure B2 (cont'd). Locations of Canadian marine finfish farms using antibiotic drugs, 2016-2018: NB – oxytetracycline (left) and florfenicol (right). Red symbols (•) are farms that reported using each antibiotic drug; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Maps are not shown for erythromycin (1 farm in BMA 1 in 2016), ormetoprim (no farms), and trimethoprim (3 farms in BMA 2a in 2016; 1 farm in BMA 2a and 1 farm in BMA 3c in BMA2017; 1 farm in BMA 1 in 2018).

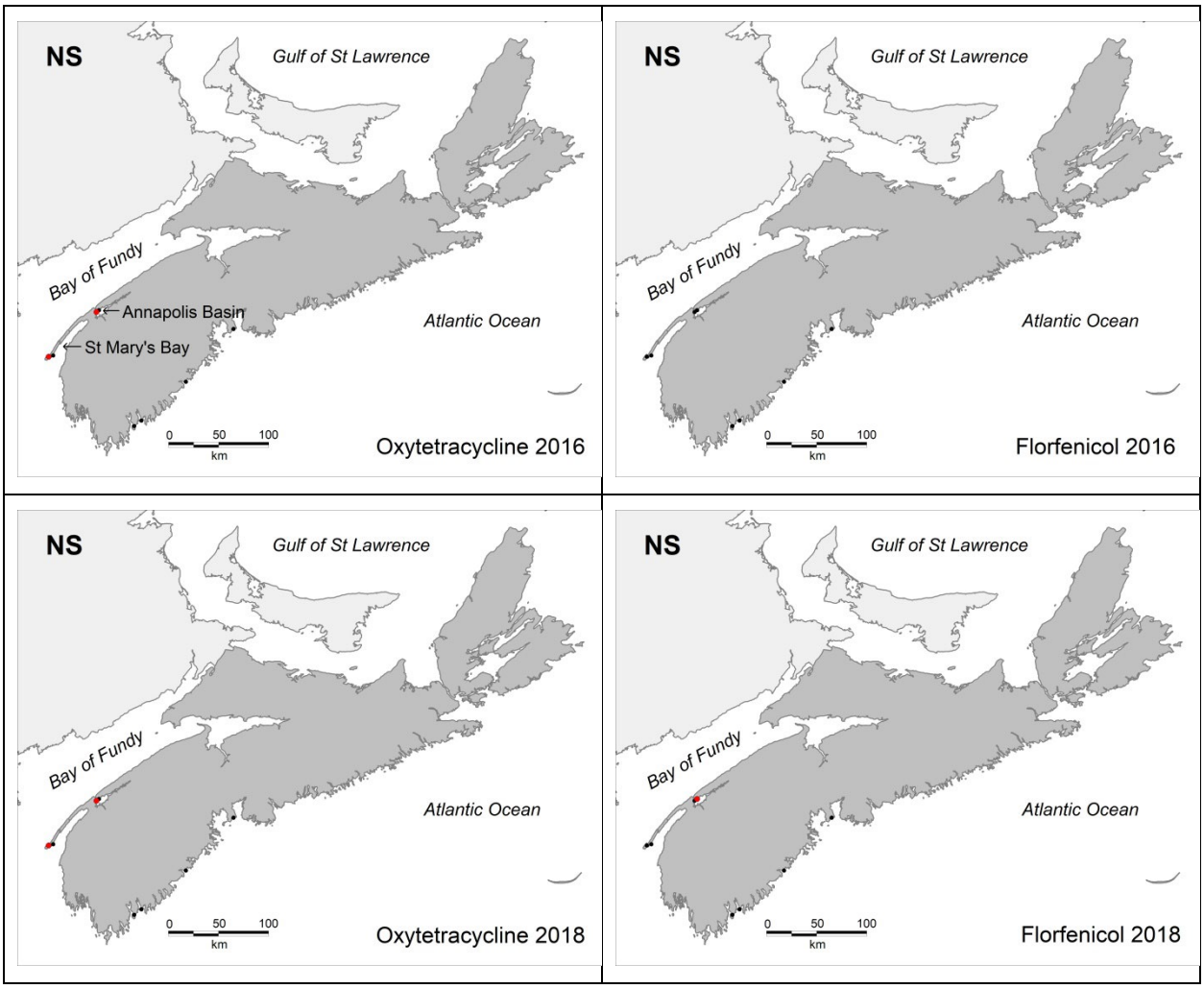

Figure B2 (cont'd). Locations of Canadian marine finfish farms using antibiotic drugs, 2016-2018: NS – oxytetracycline (left) and florfenicol (right). Red symbols (•) are farms that reported using each antibiotic drug; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). In 2016, oxytetracycline was the only antibiotic drug used in NS; in 2017, no antibiotic drugs were used in NS; in 2018, oxytetracycline and florfenicol were the only antibiotic drugs used in NS. No other drugs or pesticides were used in NS in 2016-2018.

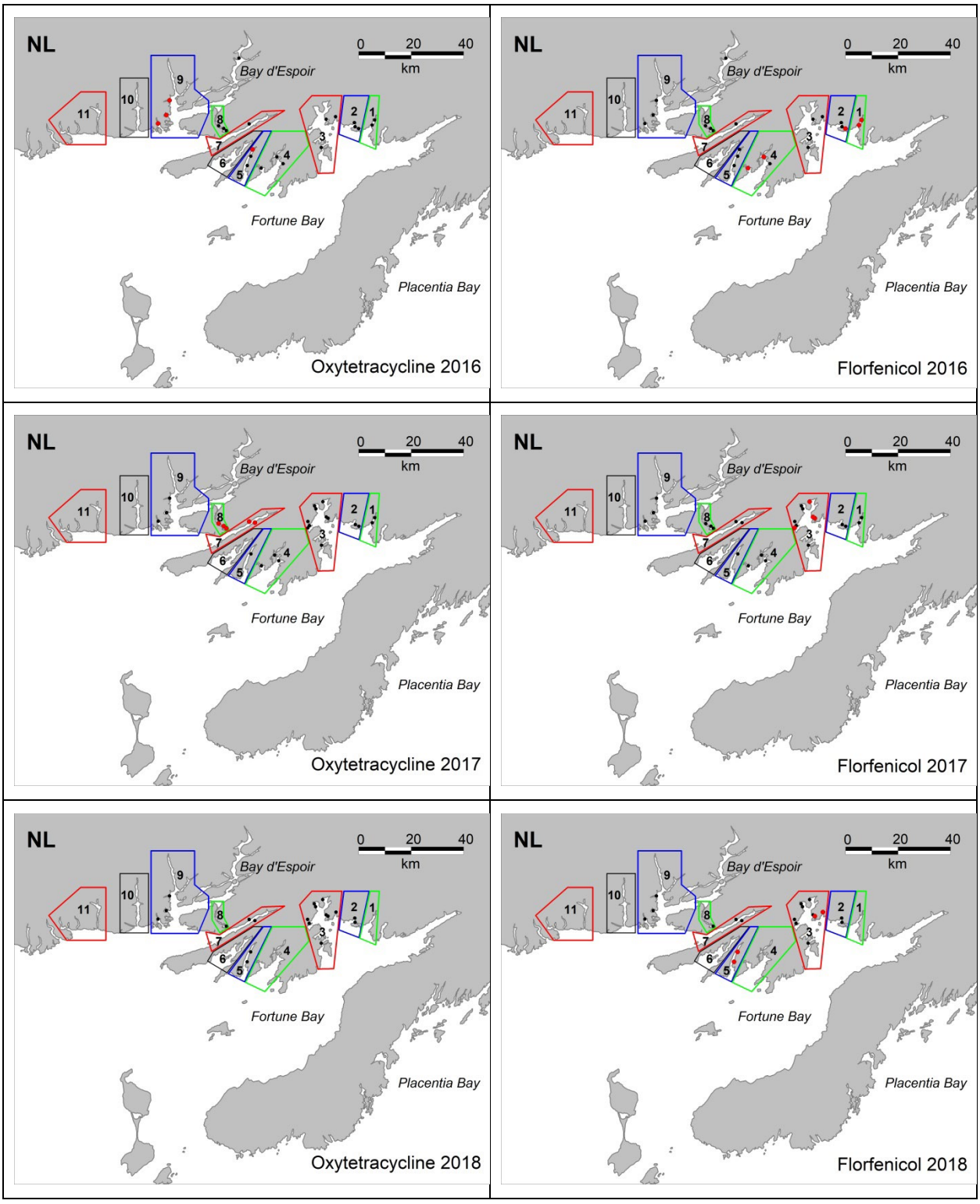

Figure B2 (concluded). Locations of Canadian marine finfish farms using antibiotic drugs, 2016-2018: NL – oxytetracycline (left) and florfenicol (right). Red symbols (•) are farms that reported using each antibiotic drug; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Oxytetracycline was not used in NL in 2018. Maps are not shown for erythromycin (1 farm in BMA 4 in 2016), ormetoprim (no farms), and trimethoprim (2 farms in BMA 4 in 2016).

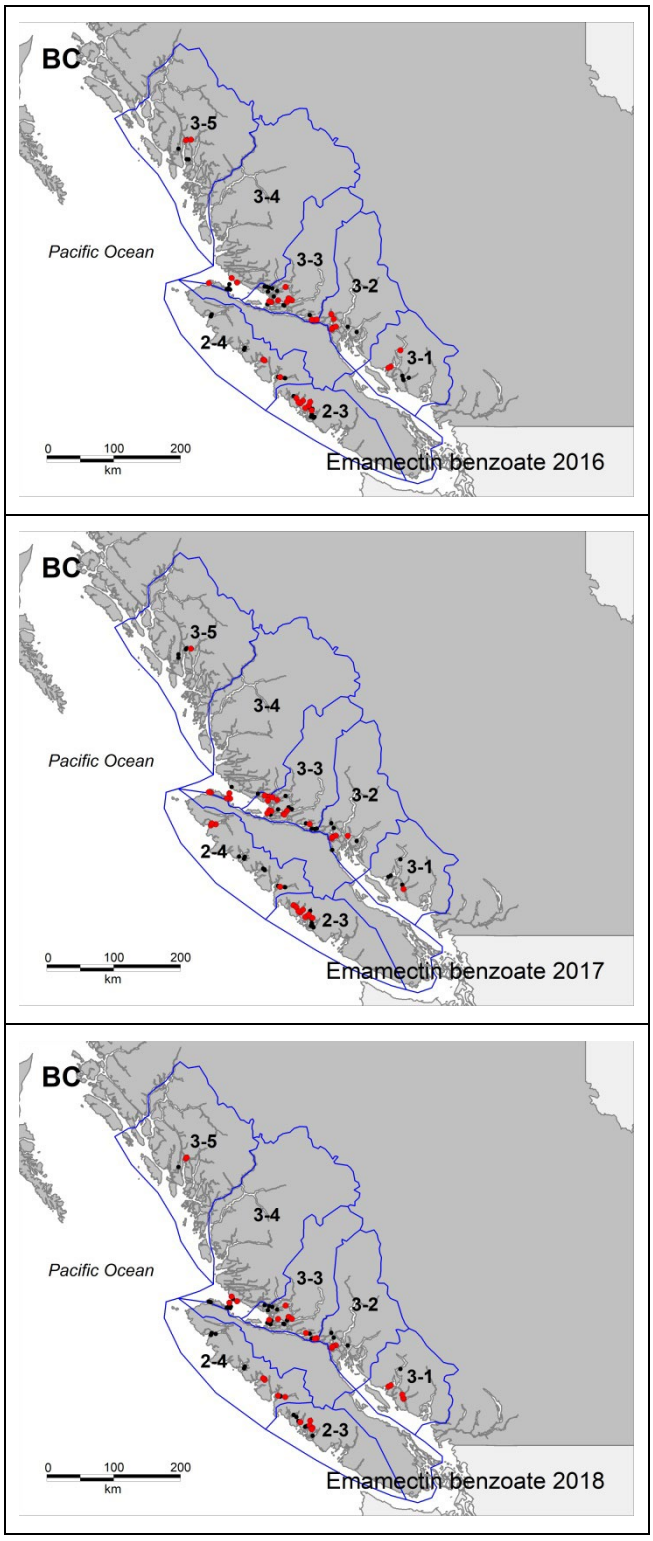

Figure B3. Locations of Canadian marine finfish farms using pest control drugs, 2016-2018: BC – emamectin benzoate. Red symbols (•) are farms that reported using emamectin benzoate; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Emamectin benzoate was the only pest control drug used in BC during 2016-2018.

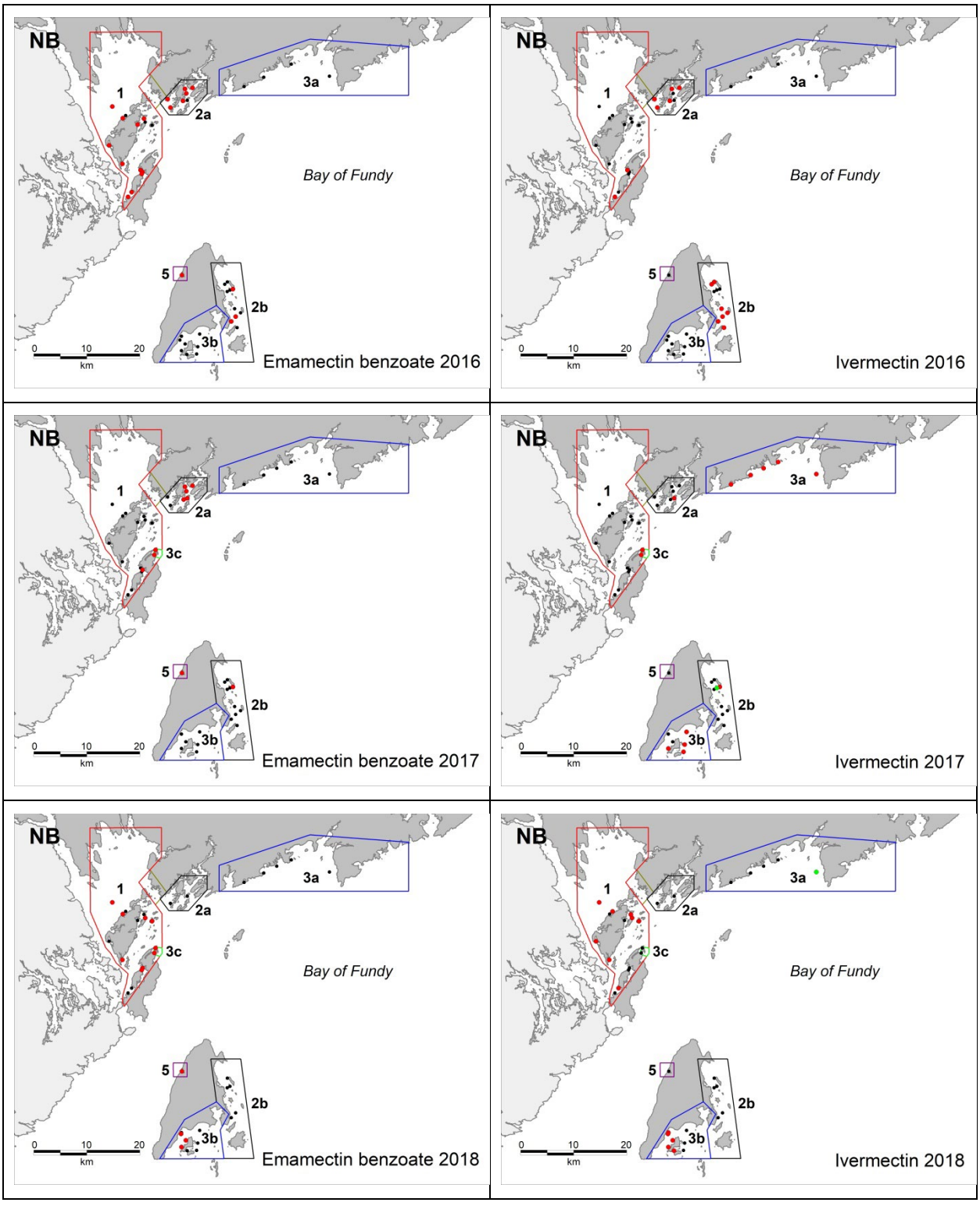

Figure B3 (cont'd). Locations of Canadian marine finfish farms using pest control drugs, 2016-2018: NB – emamectin benzoate (left) and ivermectin (right). Red symbols (•) are farms that reported using each pest control drug; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Green symbols (•) on the ivermectin maps are sites of selamectin trials: 1 farm in BMA 2b in 2017 and 1 farm in BMA 3a in 2018.

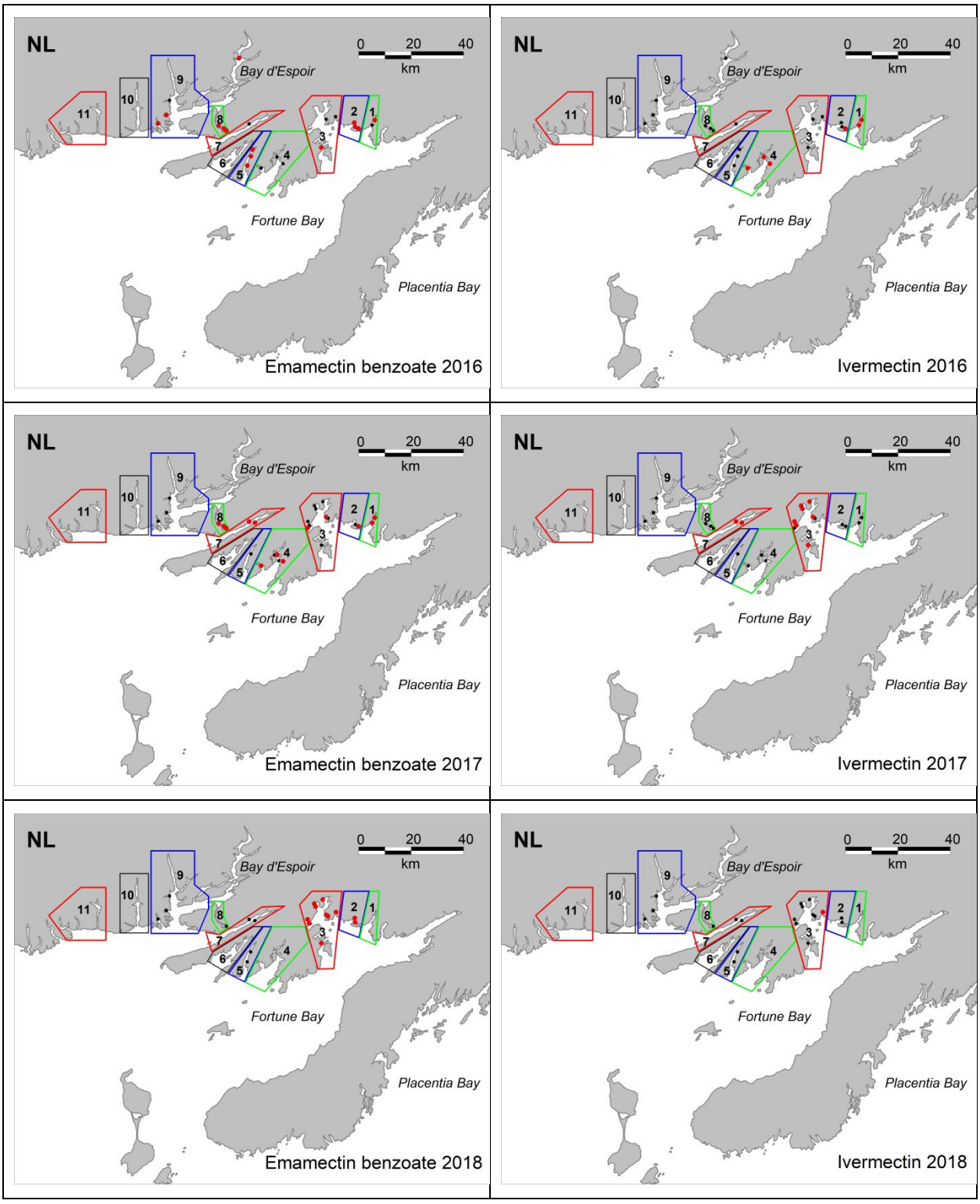

Figure B3 (cont'd). Locations of Canadian marine finfish farms using pest control drugs, 2016-2018: NL – emamectin benzoate (left) and ivermectin (right). Red symbols (•) are farms that reported using each pest control drug; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b).

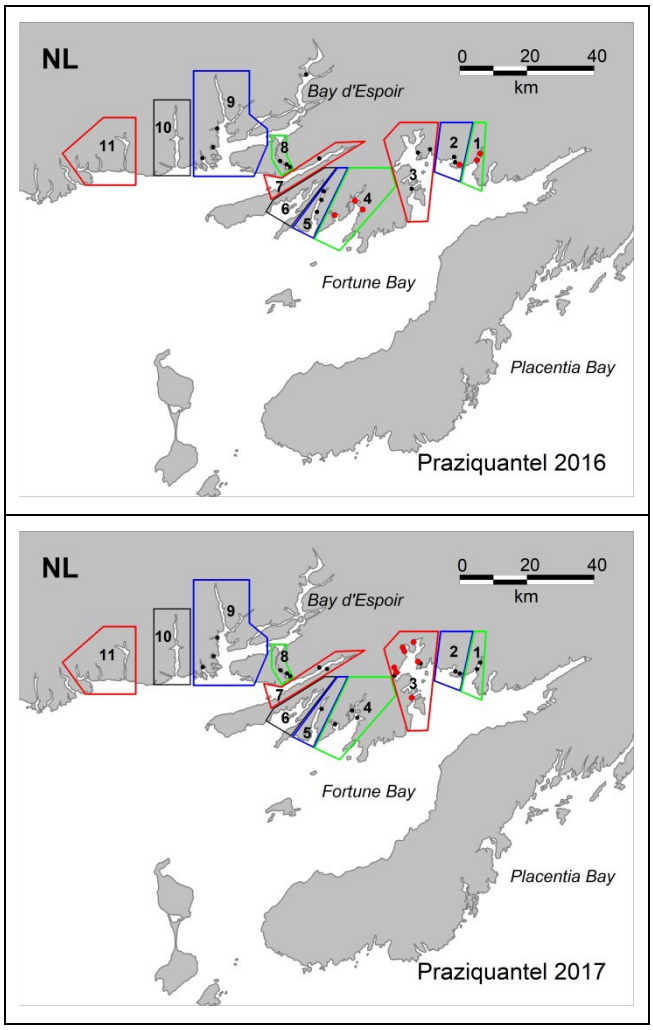

Figure B3 (concluded). Locations of Canadian marine finfish farms using pest control drugs, 2016-2018: NL – praziquantel. Red symbols (•) are farms that reported using praziquantel; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Praziquantel was not used in NL in 2018 and was not used in any other province in 2016-2018.

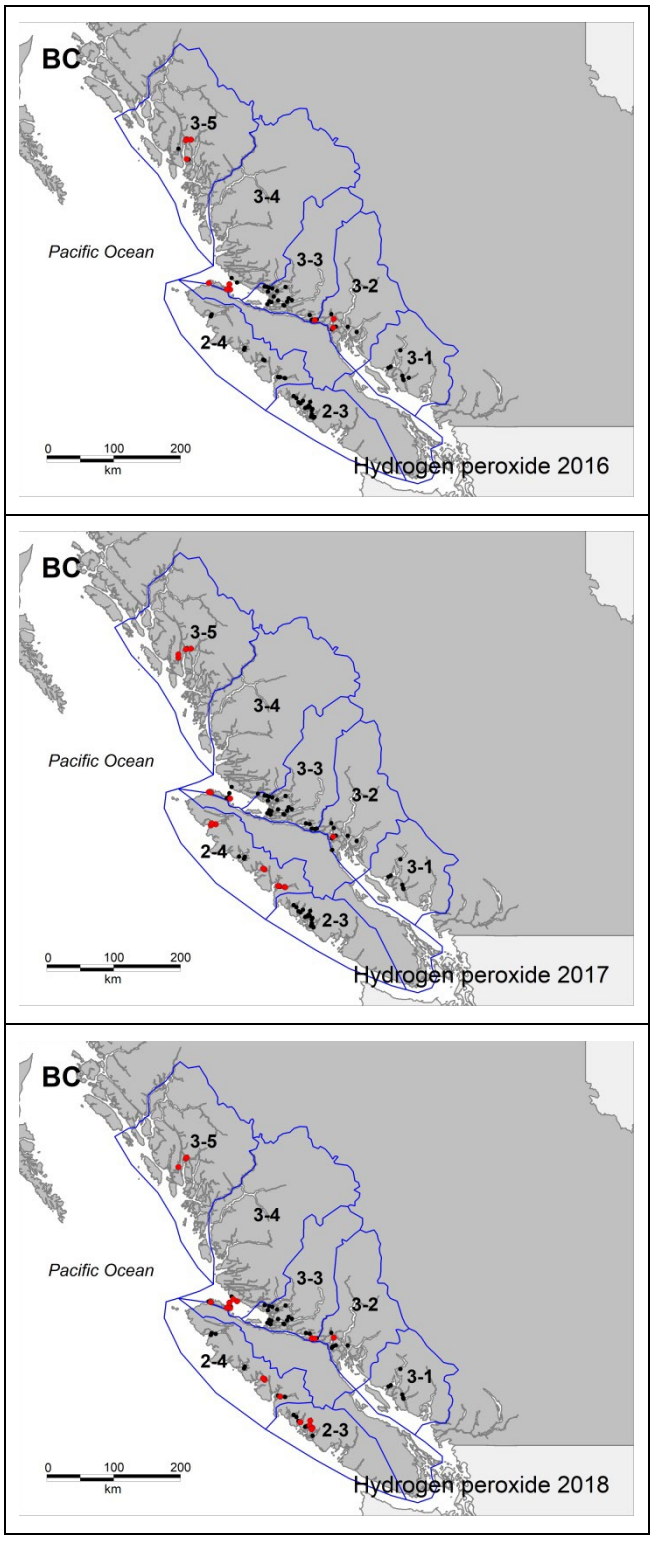

Figure B4. Locations of Canadian marine finfish farms using pesticides, 2016-2018: BC – hydrogen peroxide. Red symbols (•) are farms that reported using hydrogen peroxide; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Azamethiphos was not used in BC.

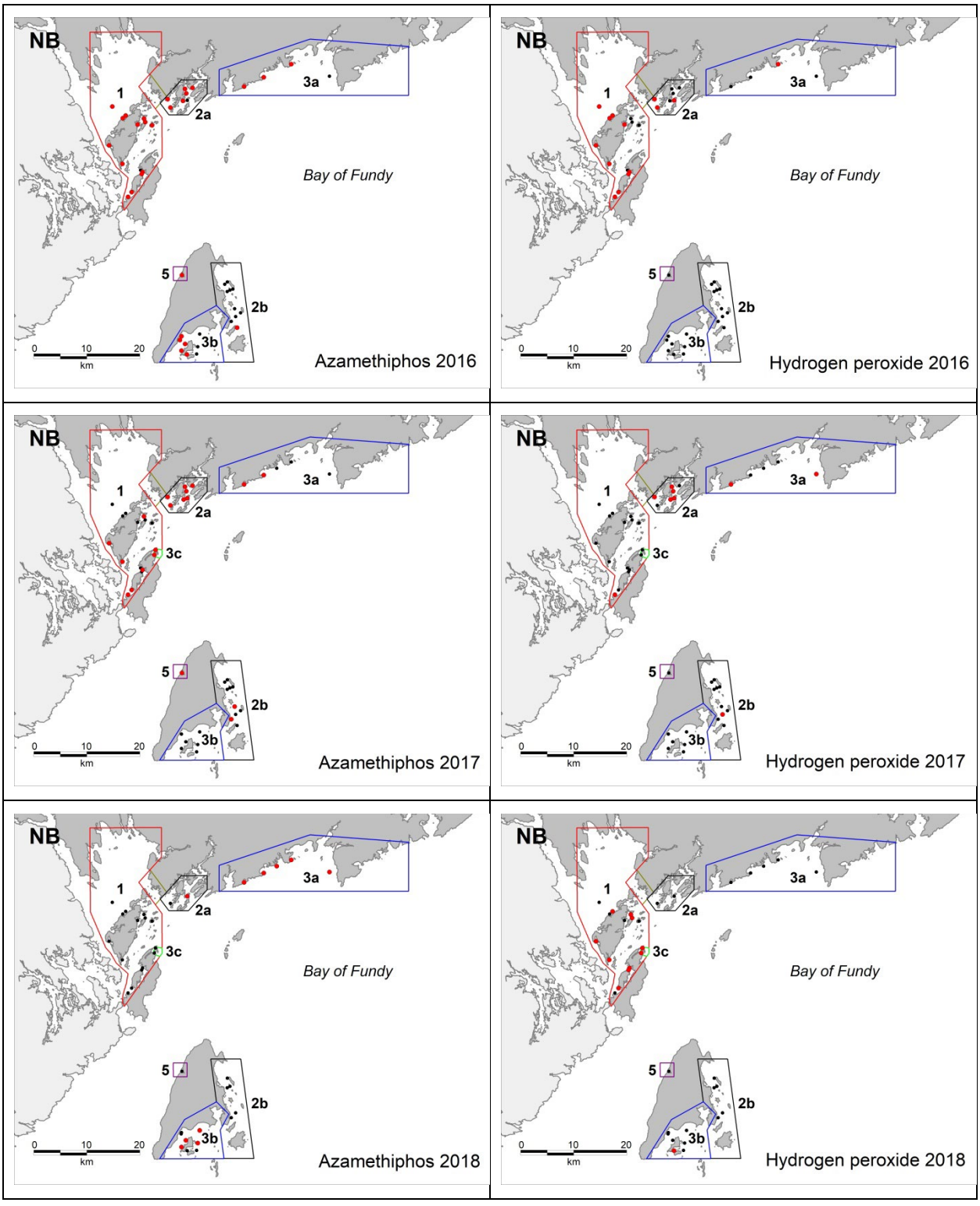

Figure B4 (cont'd). Locations of Canadian marine finfish farms using pesticides, 2016-2018: NB – azamethiphos (left) and hydrogen peroxide (right). Red symbols (•) are farms that reported each pesticide; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b).

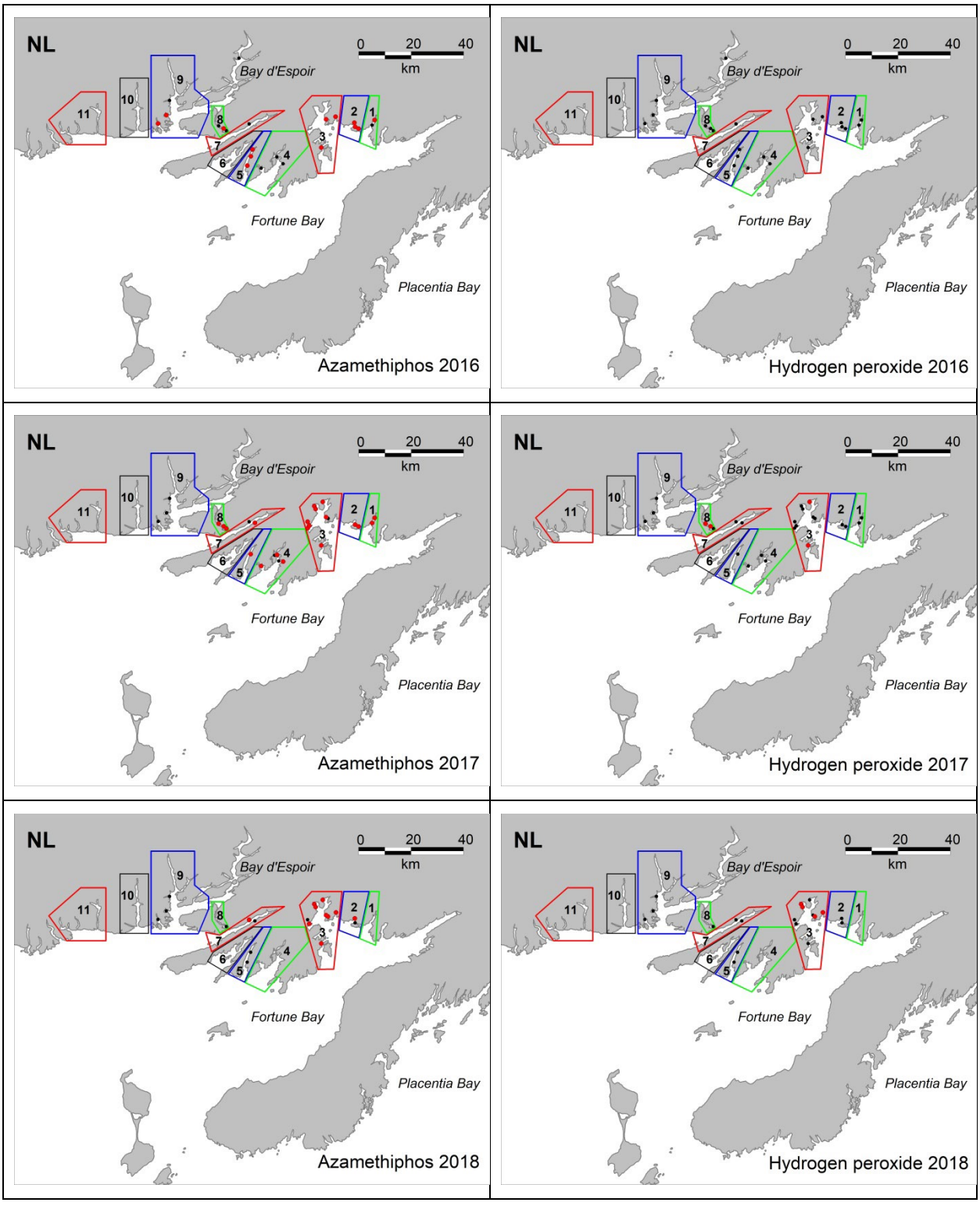

Figure B4 (concluded). Locations of Canadian marine finfish farms using pesticides, 2016-2018: NL – azamethiphos (left) and hydrogen peroxide (right). Red symbols (•) are farms that reported using each pesticide; smaller black symbols (•) are untreated farms included in the NAPRD in each year (DFO 2020b). Hydrogen peroxide was not used in NL in 2016.