Chapter

Microplastics Derived from Commercial Fishing Activities

Tore Syversen and Grethe Lilleng

Abstract

Ordinary fishing activity is a source of microplastics to the sea that is often overlooked and scarcely reported in the literature. In this paper, we estimate the number of microplastics in the ocean that originates from the wear and tear of different fishing gear used during ordinary, commercial fishing. The wear comes mainly from rope abrasion caused by the haulers and gear dragged along the sea bottom. The types of fishing gear considered are pots, gillnets, longlines, Danish seine, and trawls. Our calculations show that about 208 tons of microplastics are produced annually from the Norwegian fishery. Globally, it sums to 4 622 tons annually. However, the calculations have several questionable parameters, and these numbers must be considered a first rough estimate of the generated microplastics. More research is needed to get better estimates, particularly regarding trawl dolly ropes.

Keywords: microplastics, wear and tear, gillnet, crab pots, longlines, Danish seine, trawls, fishing ropes

1. Introduction

Plastic pollution in the sea is a widespread problem that has gained much focus recently. One of the most prominent sources of this pollution is fishing gear accounting for about 18% of the total marine plastic debris [1]. This plastic pollution causes lots of damage to the wildlife in and around the oceans. Some review papers discussing this damage are [2–8]. Furthermore, several studies have reported on the occurrence of microplastics in marine animals from the Middle East [9], Europe [10–15], Asia [16], South America [17], Africa [18], and Australia [19].

This chapter reports the plastic pollution caused by fishing gear during ordinary fishing activities, that is, wear and tear from the plastic ropes due to sea bottom contact and abrasion caused by the hauling equipment. Modern fishing gear is composed of different plastics, with polyethene (PE), polypropylene (PP), and polyamide (PA) being the most widely used [1]. These plastic ropes are worn during everyday use and regularly replaced when the wear gets too high. The amount of microplastics originating from fisheries is difficult to estimate, and the literature reports very little on the subject. However, a recent report from the University of Plymouth states that the total number of microplastic fragments in the oceans originating from the use of fishing gear in the United Kingdom can range from 326 million to 17 billion pieces annually [20]. Another study from the University of Alicante shows that the concentration of microplastics in marine sediments on the coast of Spain is higher close to the three coastal fish farms investigated [21]. There are also other sources of plastic pollution caused by fishing that we do not consider, such as lost and abandoned gear that remains in the ocean indefinitely. Lost and abandoned gear causes severe problems, such as ghost fishing [22] and entanglement [2]. A recent report claims that lost and abandoned fishing gear contributes to more than 45000 tons of plastic pollution annually [23].

The objective of this chapter is to determine the number of microplastics in the sea originating from fishing gear globally. Due to the complexity, it must be considered a first approach, aiming for better and more accurate calculations in the future. We omit small-scale fishing and consider commercial fishing only, that is, fishers having a quota and regularly delivering catch registered in the catch statistics.

2. Methodology

2.1 Causes of wear on fishing gear

The leading causes of fishing gear wear are abrasion with the sea bottom and hauling equipment. Specifically, ropes and nets dragged along the seafloor create heavy wear on trawls and Danish Seine ropes, and for these gear types, it is common to change the parts that are in contact with the sea bottom after 1–2 years and in some cases even more often. The extent of wear depends on the seafloor condition, meaning that a rocky bottom creates much more wear than a sandy bottom.

Another significant cause of abrasion is the onboard hauling equipment. Hydraulic net haulers, as shown in **Figure 4**, or net drums are the two most common haulers in use, and for both, the heavy stress caused by the ropes pressing toward the equipment causes abrasion that gradually tears down the ropes. For the net hauler, the rope is squeezed between two plates, creating even more stress on the rope.

In addition to the gradual abrasion caused by contact, plastic ropes also get degraded by other causes. The most common is UV radiation, leading to the fragmentation of the plastic fibers. Fishing gear is constantly exposed to UV radiation, and proper storing of the gear is essential to prevent degradation. In addition, fragmented plastic ropes have accelerated wear when in contact with the hauler or the seafloor. According to a study from the United Kingdom, plastic ropes lying in the sea at 10 m depth lose an average of 0.39% (PP), 1.02% (PA), and 0.45% (PE) per month caused by abrasion due to UV radiation [24].

Also, gear dragged in the water wears due to the friction force between water and gear. This effect is much less than bottom contact but still significant, combined with the fragmentation effect caused by UV radiation. However, dragging occurs mainly during hauling, and the hauling equipment is considered a much more significant source of depletion.

2.2 Methodological approach

The research and reports on the wear and tear of fishing gear are scarce. Thus, we need to establish a methodology we can use to approach the solution. Due to the complexity, it requires an enormous effort to get exact numbers of microplastics generated from fishing gear. Instead, our goal is to get a rough estimate of the number of microplastics in the sea to get a feeling of how severe the problem is and determine which fishing gear causes the most pollution.

For each fishing gear considered, we interviewed five fishers to get basic information on their use of the gear. This information includes the average number of gear in use, the length of the ropes, the average lifetime, and their estimate of the wear and tear when the gear is replaced. In addition, we checked some of these figures against the sales figures from leading gear manufacturers. Furthermore, the Norwegian statistics for fisheries [25] provide the number of vessels for each fishing gear and their total catch.

Additionally, we collected samples from dispatched gear, mainly seine ropes and longlines, and measured the diameter and weight of the ropes to calculate the depletion. These calculations were then compared with the information from the fishers, further providing a better estimate of the wear and tear. The result gives the average percentage of wear for each type of fishing gear. We then calculate the total wear and tear by finding the total number of gear used.

Expanding the scope to include all fishing gear worldwide is indeed a challenging exercise. Unfortunately, an overview of all fishing vessels and their gear is not readily available, nor are the conditions for their fishing. Therefore, we must settle for rough estimations. We have statistical data for the global catch produced by FAO since 1950 [26], and our first approach is to use this data and assume the same conditions apply to other nations than Norway. In this way, we assume the amount of microplastics generated per ton of fish is equal for every nation. Using the statistical data from FAO [26], we find that Norway accounts for about 3.0% of all catches worldwide, which is a starting point for our calculations.

3. Danish seine

In a recent report, we have described the plastic pollution caused by the Danish seine fishery [27]. Therefore, we do not go into detail but briefly describe this fishing gear and the main findings. For details, we refer to [27].

3.1 Usage and causes of wear

The Danish seine comprises a conical net with rope arms at each side. The ropes usually have a steel wire core since they must withstand heavy forces when dragged along the seabed. Several variants of this fishing method exist, including the original Danish seine method, called Anchor seining. Other methods are fly-dragging, also called Scottish seine, and tow-dragging, also called the Japanese method. For all of these variants, the rope arms are dragged along the seabed while the net wraps around the catch. The rope arms may be several kilometers in length. The sea bottom contact tears heavily on the ropes, and usually, the fishers replace them after 18 months. This replacement rate may be specific for Norway and possibly differ for other countries' fisheries.

3.2 Calculated wear

By comparing the weight of new and used seine ropes, we estimate the loss due wear and tear. Furthermore, based on interviews with the fishers, we get statistics on the ropes used. We calculate the annual wear on the Danish seine fishery in Norway to be 77–97 t plastic. These figures depend on several factors, such as the average lifetime, sea bottom conditions, stretching of the ropes, and the average rope arm length and number of seine in use. In other words, there are many possible sources of error, but we believe we are close to the actual value. Then, by finding the number of vessels in use for other countries and assuming the same wear is also valid, we estimate the annual worldwide plastic pollution from seine fishery to be about 311 t [27].

4. Bottom trawl

4.1 Usage and causes of microplastics

Bottom-trawl fishing, i.e., beam trawls, otter trawls, and dredges, is used worldwide and provides about a quarter of the marine catch [28]. A rich body of literature assesses the impacts of sea bottom trawling on benthic invertebrate disturbances and seabed alterations [29, 30]. However, research on the wear and tear of sea bottom trawl remains relatively understudied.

In Norway, the rockhopper ground gear has been commonly used in the sea bottom trawl fisheries for the last 30 years. In contrast to the previously used bobbin ground gear, the rockhopper has shown improved catch efficiency for Haddock (*Melanogrammus aeglefinus*) and Atlantic Cod (*Gadus morhua*) due to its increased contact with the seabed [31].

The trawl comprises trawl doors, bridles, sweeps, and ground gear (rockhopper). The fish is caught by dragging the trawl net along the seabed. The water is released through the net mesh, and the fish remains in the trawl bag. The ground gear consists of steel and rubber, while the wipers and doors consist of steel. Dolly ropes or other protective ropes used to protect the net consist of bundles of plastic (PE) threads. The ground gear discs are made from old dump truck tires and threaded onto heavy wires or chains. The most common are discs of 21 inches in diameter, but on the rough seafloor or when fishing for halibut, the discs can be 24 inches. The material composition of a standard dump truck tire is approximately one-third natural rubber, while the rest is a mixture of synthetic rubber and filler.

The lifespan of a sea bottom trawl depends on several factors, such as seabed composition, trawl type, traction speed, and local hydrodynamic forces (i.e., current). However, the seabed condition, like the roughness, is the decisive factor in how quickly the trawl components wear. Areas with fungus, followed by stone or rocky bottoms, are abrasive, while clay is the most gentle seafloor type. It is difficult to estimate the wear and tear on the trawl net itself. The line is rarely so worn that it peels off. Before this occurs, sections are exchanged or the line repaired. Fishers replace the protecting net regularly, but exact replacement rates are challenging to obtain from fishers and manufacturers. However, it is possible to estimate wear on the ground gear, which the fishers replace when worn out.

4.2 Calculated wear

To calculate the annual mass loss from the rockhopper gear, L_{rh}, we use the following equation:

$$L_{rh} = N_{disc} W_{disc} N_{tw} N_v P_w \frac{12}{LT} \tag{1}$$

Here, N_{disc} is the number of discs at the rockhopper, W_{disc} is the weight of each disc, N_{tw} is the number of trawls in use, N_v is the number of vessels, P_w is the average percentage wear when replaced, and LT is the average lifetime in months (**Figure 1**).

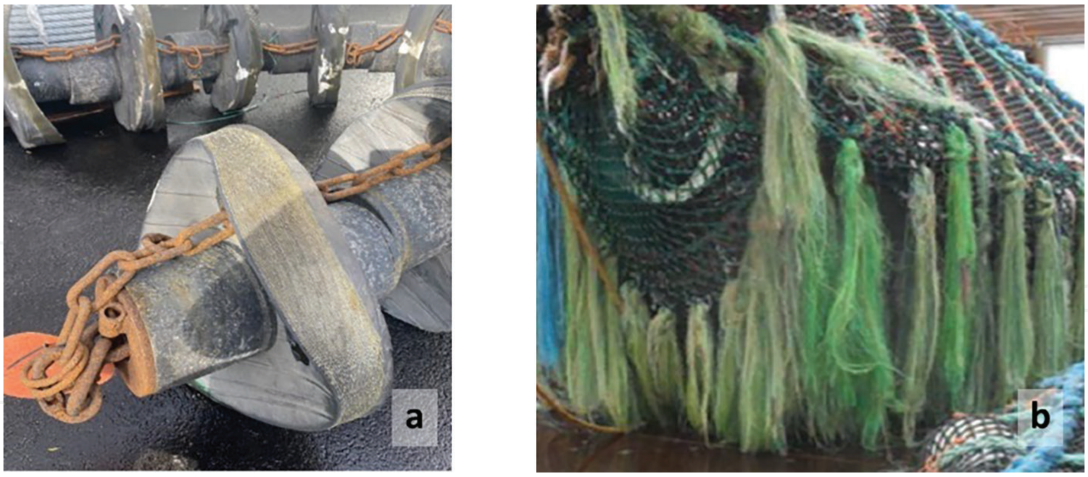

Figure 1.
Worn-out rockhopper gear (a) and dolly rope used to protect the trawl (b). Photo: SINTEF.

In conversations with Norwegian shipping companies and gear manufacturers, Norwegian vessels mainly use 21-inch discs weighing between 20 and 23 kg, depending on the manufacturer. Thus, in the calculations, we used a weight per disc $W_{disc} = 21$ kg. Gear has five sections, two starboards, two ports, and one center gear. Each section consists of 21 discs, giving a total of $N_{disc} = 105$.

A rockhopper gear is touching the seafloor in all its length and thus causing massive depletion of the gear, see **Figure 1a**. The manufacturers state that the gear is replaced every 6–10 months, at which they are approximately 20% worn. However, the fishers in our study claim the gear last longer, approximately 12–18 months, but with more significant wear, usually 30–40%. In our calculations, we make a sober estimate of the lifetime to 10 months for a standard gear with a percentage weight loss of 20%. The wear is vessel-specific, so these numbers must be considered average for the fleet.

We consider only vessels that delivered more than 100 t catch during 2019, in which case the number of vessels is 63. Half of them use twin trawl. **Table 1** summarizes the calculations on wear and tear from rockhopper gear, which is close to 50 t annually.

The protecting ropes, like dolly ropes, are also heavily exposed to wear and tear. A Dutch research consortium, DollyRopeFree, has reported weight loss of 10–25% after 2 weeks of use [32]. Unfortunately, they do not mention from which type of trawl the samples were taken. We have not been able to calculate the annual plastic fragmentation from dolly ropes due to a lack of information. However, there is no doubt that dolly ropes and other protective ropes contribute to plastic debris in the ocean on a large scale. A worn dolly rope is shown in **Figure 1b**.

	N_{discs}	W_{discs}	N_{tw}	N_v	P_w	LT	L_{rh}
Single trawl	105	21 kg	1	32	20%	10 months	16.9 t
Twin trawl	105	21 kg	2	31	20%	10 months	32.8 t
Total							49.7 t

Table 1.
Calculated annual mass loss from rockhopper gear.

4.3 Trawling worldwide

Unfortunately, there are no registrations on trawlers worldwide, making it difficult to estimate the global share of microplastics from this gear. Also, the catch statistics are difficult to use since they are sorted by species, not gear type. Therefore, acknowledging that the Norwegian catch share is about 3% is the only way, we can now estimate the global loss. Hence, using the Norwegian numbers for trawl and dividing by the Norwegian share, we end up with a total global microplastic loss due to trawls of 1 656 t.

5. Gillnets

5.1 Usage and causes of microplastics

Gillnets are the most important commercial fishing gear for the Norwegian coastal fleet, where cod (*Gadus morhua*) and saithe (*Pollachius virens*) are the most important target species. In 2019, 74 864 t cod and 32 032 t saithe were caught using this gear.

A gillnet consists of the float line, the lead line, and the netting. The float and lead lines usually consist of polypropylene and polyethene, but the lead line also has lead inside the core to make it sink. In addition, a drop line connects to a buoy at the sea surface. The drop line consists of polypropylene and polyethene at the lower part and polyester at the upper part. The netting consists of single or multistrand monofilament nylon.

The lifetime of a gillnet is highly variable and based on geographical location, vessel size, and hauling frequency, which in turn depends on the type of fishing. For example, some vessels fish all year round and replace a thousand nets yearly. Others, who only operate during the cod season, may replace the net each 4–5 years, or even after10 years. Also, as for the trawl, there are significant variations in the lifetime depending on the seabed quality.

Drop and float lines are rarely in contact with the seafloor, and abrasion mainly occurs during hauling and setting. Although it is challenging to calculate wear and tear solely from the hauling equipment, gillnet fishing at great depth causes more significant stretches and squeezes during hauling than fishing in relatively shallow waters. Blue halibut is one of the species caught at such great depth. Lead lines, on the other hand, are more prominent to wear and tear due to their contact with the sea bottom. **Figure 2** shows an example of a worn-out lead line (a) and a typical gillnet hauler (b). The ropes are squeezed between two plates at the hauler, creating

Figure 2.
Worn-out lead line (a) and a typical gillnet hauler (b). Photo: SINTEF.

significant abrasion. Another common type of hauler is the drum winch, which also creates abrasion of the ropes but is much more gentle.

5.2 Calculated wear and tear

To estimate the wear and tear on gillnets, we need knowledge of several parameters, such as the average number of gillnets per vessel, the thickness of the ropes, the average lifetime, and the average percentage mass loss. We got these numbers from our interviews with fishers, confirmed by information from gear suppliers.

On average, a fisher has 200 gillnets consisting of netting, lead, and float lines. They are tied in strings of different lengths, where the length of each component is 27.5 m. The total length (L_G) of all 200 gillnets is 5500 m. In addition, a fisher has 2000 m of drop lines on average. For the netting, the weight is 2.2 kg for one net, i.e., the complete 27.5-meter length, giving a weight per meter (W_m) of 80 g. For the drop line, 14 mm is the typical diameter, weighing 88 g per meter. For the float line, a 15 mm rope is used with a weight of 100 g per meter, and for the lead line, a 12 mm diameter is used with a weight of 73 g per meter, excluding the lead.

Next, we have to estimate the annual loss percentage. The fishers estimate a percentage loss, P_L, of about 8% when the ropes are worn out, and for the average lifetime (LT), they estimate 15 years for lead lines, 20 years for float lines, and 25 years for drop lines. The numbers are based on an average of 40–60 trips per year. The netting is replaced every 4 years on average. The netting often gets stuck in rocks at the sea bottom, creating holes and small pieces that are torn apart. Due to this, it must be replaced more often. We estimate a loss percentage of 3%, giving an annual loss percentage of 0.75%. To calculate the annual loss (L) for each component, we then use the following formulae:

$$L = N_V L_G W_m P_L / LT \tag{2}$$

Table 2 shows the calculated loss per component and vessel and the total loss per fleet. According to the Norwegian statistics for fisheries [25], the number of vessels using gillnets is N_V = 1472.

5.3 Gillnets worldwide

Gillnets are perhaps the most used fishing gear worldwide. However, in many areas, there are differences in use from the Norwegian method described above.

	L_g (m)	W_m (kg)	W_G (kg)	P_L	LT (years)	L_V (kg)	L (kg)
Lead lines	5 500	0.073	401.5	15%	15	4.02	5 910
Float lines	5 500	0.1	550	15%	20	4.13	6 072
Drop lines	2 000	0.088	176	15%	25	1.06	1 554
Netting	5 500	0.08	440	3%	4	3.3	4 857
Total							18 394

Table 2.
Calculated annual microplastics loss from gillnets per vessel and total per fleet.

Smaller boats are typical, with other types of equipment and ropes with other dimensions. Therefore, estimating the global amount of microplastics based on Norwegian numbers is very challenging. Our approach is to use the Norwegian numbers and divide them by the estimated Norwegian share of the total catch. Unfortunately, the statistics are grouped on species, not gear type, meaning we cannot know the Norwegian catch share for a specific gear type. To overcome this problem, we assume the catch share for gillnets is the same as the total catch share for all gears in use. This approach is a gross simplification, which we have to keep in mind.

According to FIGIS [26], Norway accounts for 3.0% of the total catch of marine and diadromous species. Thus, the global amount of microplastics generated from gillnets estimates to 613.1 t.

6. Pots

6.1 Usage and causes of microplastics

Crab pots are tied in strings, but the number of pots in each string varies on the type of fishery. They come in many different shapes, but the basic idea is to trap the crabs inside the pots. King crab pots are collapsible to ease storage, and Snow crab pots are conical so that they can be stacked.

In Norway, we have identified 426 vessels catching crabs based on the criteria that they have landed more than 400 kg per year. On average, we assume 15 strings with 15 pots per string, based on the interviews with fishers. The pots usually stand at 30–40 m depth with 20 m spacing. In addition, we have 772 vessels fishing for King crab in the northern part of Norway. For King crab, the depth is about 200 m, which causes more stress and more wear on the ropes during hauling. The typical rope diameter is 10 mm. There are different rope qualities, mostly polypropylene, polyethene, or nylon.

Fishing for snow crab takes place in the Barents Sea (Norwegian and Russian fishers) and the Northwest Atlantic and North Pacific, usually at depths of 220–300 m. A large number of pots in the string is typical for snow crab fishery, usually 200 on average. The ropes typically have a diameter of 22–24 mm due to the heavy stress they are exposed to. Thus, the rope thickness and number of pots are unique for this type of fishery. The pots have a conical shape, as seen in **Figure 3a**. A vessel fishing for snow crab may have 35 strings and thus a total of 7500 pots.

The hauling equipment is the most significant cause of wear and tear on the drop line and the connecting ropes between the pots. Ropes are hauled quickly from a depth of 220–300 m, causing significant abrasion. The winch also contributes to wear and tear on the ropes, pulling the ropes backward and through the boat to the bins behind.

Also, the plastic coating around the steel cracks during use, but there are significant differences in the quality and how much it cracks. Some of the cheaper pots are of low quality and tend to rust. When the iron rusts, the plastic coating explodes, as seen in **Figure 3b**, releasing large plastic flakes into the sea. We do not include the plastic originating from this coating in our calculations.

6.2 Calculated wear

To estimate the wear on the ropes, we distinguish between Snow crabs and other crabs and lobsters. Then we find the number of vessels involved in both categories and estimate the length of the ropes based on the average number of strings and pots

Figure 3.
Snow crab pot (a), with cracked coating (b). Photo: SINTEF.

in each string. Finally, we estimate the average wear percentage based on fishers' and manufacturers' information.

For crabs and lobsters, the total number of vessels involved in Norway is 1198, half of them catching King crab. The average number of pots at each vessel depends on the type of crab, but we use 100 pots divided into 10 strings with 10 pots each. The distance between each pot is 20 m, and the drop line length is 50 m on average.

For snow crabs, there are only nine active vessels. After dialogue with the fishermen, we estimate an average of 7000 pots, spread over 35 strings with 200 pots in each string. The typical distance between each pot is 30 meters. The drop line at each end of the string is usually three coils of 110 meters.

To calculate the total length of ropes (L_R) for the whole fleet, we use the following formula:

$$L_R = N_V N_s \left[L_d + \left(N_p - 1 \right) L_i \right] \tag{3}$$

Here, N_V is the number of vessels, N_s is the average number of strings, N_p is the number of pots in a string, L_d is the dropline length, and L_i is the rope length between the pots in the string. The above information is summarized in **Table 3**, where the length calculations are based on Eq. (3).

Finally, we calculate the annual mass loss (L) due to wear and tear from Eq. (4):

$$L = W_m L_R P_L \tag{4}$$

Here, W_m is the rope weight per meter, and P_L is the annual percentage loss. Finally, W_T in **Table 4** is the total rope weight. In particular, the annual loss percentage is challenging to estimate. However, the results from [24] can be used as a starting point. The ropes are mainly PP/PE, and [24] suggests a monthly mass loss of 0.4% for

Category	N_V	N_P	N_S	L_i	L_d	L_R (m)
Snow crab	9	200	35	30	660	2 088 450
Other crabs	1198	10	10	20	50	2 755 400
Lobster	50	5	10	20	50	65 000

Table 3.
Calculation of the total rope lengths in meters for crab fishery in Norway.

Category	W_m (kg)	L_R (m)	W_T (kg)	P_L	L (kg)
Snow crabs	0.259	2 088 450	540 909	2.5%	13 523
Other crabs	0.045	2 755 400	123 993	1.5%	1 860
Lobster	0.045	65 000	2 925	1.5%	44
Total					15 427

Table 4.
Calculation of the annual amount of microplastics due to crab fishing in Norway.

such ropes just by lying in the sea. Additionally, the haulers contribute significantly to this loss. Since the ropes are not constantly in the sea, and their lifetime often is 10 years or more, we estimate an annual loss percentage of 1.5% for crab and lobster pots. The loss is set to 2.5% annually for snow crab ropes since the stress is much higher. The results are then summarized in **Table 4**.

6.3 Pots worldwide

Crabs and lobsters are caught all over the world. Asia is the most significant area, with China and Indonesia as the leading nations. For lobster, Canada is the primary nation.

In Norway, King crab and Snow crab (Queen crab) represent a significant source of income for the Norwegian seafood industry and are commercially more valuable than other crab types. Worldwide, Canada is the leading nation in fishing for Snow crab, but the USA, Japan, Russia, and Greenland are also active nations. However, there are significant differences in the use of snow crab pots compared with other pots, as previously explained; hence, we consider them separately. **Table 5** shows the crab catch in 2019 divided by type and area. Worldwide, snow crabs account for only 13% of the total crab and lobster catch.

The total catch of Snow- or Queen crabs worldwide is 116 748 t. Out of this, Norway accounts for 3.5%. The total catch for crabs is 1 461 581, and the majority is from Asia. Norway accounts only for 0.5% of the total crab catch. Finally, the total lobster catch is 320 057 t, where Norway accounts for 0.1% of the catch.

To estimate the total global generated microplastics from crab fishery, we use data from **Table 5** and divide by the Norwegian share. The results are shown in **Table 6**.

In Norway, fishing for Snow crabs is the main contributor to microplastics, even with a small number of vessels involved. However, other crabs account for the more significant part of the wear and tear worldwide. The global amount of microplastics originating from the crab fishery is 802.2 t.

	Total	Africa	Asia	Oceania	America	Europe	Norway
Snow (Queen) crab, catch in tons	116 748		13 200		89 678	13 870	4 049
Other crabs, catch in tons	1 461 581	42 380	1 085 526	1 762	180 072	151 840	7 078
Lobster, catch in tons	320 057	16 966	15 907	13 845	208 041	65 298	433

Table 5.
Crab catch in 2019 divided by type and area — derived from [26].

Category	Microplastic loss in Norway (kg)	Norwegian share	Annual worldwide microplastic loss (kg)
Snow crab	13 523	3.5%	386 363
Other crabs	1 860	0.5%	371 979
Lobster	44	0.1%	43 875
Total	15 427		802 217

Table 6.
Annual worldwide microplastics generated from crab fishery.

7. Longlining

In longline fishing, we distinguish between three different modes of operation: bottom longline, surface longline, and autoline. In Norway, autoliners in the high seas account for 70% of the total catch. This fleet consists of 20 vessels, and the total annual catch in 2019 from this segment was 57 428 t. Target species are demersal fish, such as cod and saithe.

A longline consists of a long rope (the mainline) attached to branch lines with hooks. The mainline is a multifilament line (polyester and polyamide) consisting of three or four cord sections twisted together to form a long rope. The length can be up to 180 kilometers. Depending on the fishery, the mainline generally ranges from 4 to 11 mm in diameter. The supply is made of polyester, but the hooks, swivels, and stoppers are steel; see **Figure 4a**.

7.1 Usage and causes of microplastics

Most of the wear and tear occur during hauling. Hauling is performed by a powered line hauler, where the rail roller guides the longline over the rail of the ship before the de-hooker and hook cleaner remove the fish and unused bait from the hooks. Furthermore, the twist remover takes out the twist in the line before the hook separator guides the hook into the storage rack, where they are held in magazines.

Figure 4.
Autoline with stoppers, swivels, and clamps (a) and a worn-out autoline with the cords split apart (b). Photo: SINTEF.

On a traditional autoline vessel, the hauling equipment is located on the vessel's starboard side. However, there has been a shift toward hauling through moonpools in the center of the vessels. As the moonpool is placed with the lowest magnitude, it may reduce wear on the line. However, this is only an assumption as no such research exists in the area.

7.2 Calculated wear

To calculate the annual mass loss due to wear and tear from longlines (L), we use the following formulae:

$$L = N_V N_l L_l W_m P_L / LT \tag{5}$$

N_V is the number of vessels in the fleet, which we get from the Norwegian statistics for fisheries [25]. N_l is the average number of lines for each vessel, L_l is the average length of each line, W_m is the average weight per meter, P_L is the average percentage loss when the line is worn-out, and LT is the average lifetime. All of these parameters were acquired through our interviews with fishers.

Additionally, we got one worn-out line, **Figure 4b**, which we measured to establish the mass loss. This line has been in operation for 1.5 years and has been hauled approximately 300 times. A new line is 180 m long and weighs 16 kg. Our worn-out line weighs 14.9 kg, thus reduced by 1.9 kg. This gives a percentage loss of 11.9%, which coincides with what our fishers told us (12%). Measuring only one line does not give a statistically sound result, but it underpins the statements from the fishers.

Table 7 shows the calculated loss for longlines and the parameters used for the calculations Eq. (5). We split the lines into four categories as each category's parameters differ. The total loss from longlines sums to 37.2 t annually.

7.3 Longlining worldwide

As for gillnets, we cannot provide well-founded numbers on the usage of longliners worldwide. Typically, longlines are used to catch tuna in Japan, Taiwan, Korea, Cuba, and Oceania. Other nations use longlines to catch halibut in the northern

	N_V	N_l	L_l (m)	W_m (kg)	P_L	LT (years)	L (kg)
Autoline, high seas	20	500	180	0.078	12%	1.5	11 232
Autoline, coastal	53	80	180	0.100	12%	1.5	6 105
Bottom longline	415	120	540	0.035	8%	4	18 824
Surface longline	103	120	540	0.013	5%	4	1 042
Total							37 205

Table 7.
Calculated annual mass loss for different types of longlines.

Pacific. Therefore, our best estimate is to use the method for gillnets, assuming the Norwegian share of worldwide longline use is about 3%. In that case, the total microplastics from longlining worldwide is 1 240 t.

8. Discussion

8.1 On the methodology

The methodology is based on interviews with fishers to acquire essential parameters we need to calculate loss from gear. The annual loss percentage is a crucial parameter we have tried to check using different methods, such as measuring worn-out ropes and using numbers from the literature [24]. However, the many uncertainties are a weakness of the study. To get better estimates, we believe performing comprehensive studies on different types of worn-out gear is the way forward.

For calculating the global wear and tear, we need access to the number of gears used globally for each gear type. This may be available for some countries but is very hard to find. In addition, statistical parameters, such as rope lengths, diameters, and average lifetime, are necessary to perform reliable calculations for different areas. We acknowledge that our methodology for finding the global wear and tear on fishing gear has many weaknesses, but on the other hand, it is the best we can do for now. Improving the methodology is an important area for future work.

8.2 The results

Table 8 summarizes the worldwide microplastics generated from the wear and tear of the different fishing gear we have considered, together with the Norwegian numbers. We have used the Norwegian fishing fleet as the basis for our calculations. Although the Norwegian numbers are uncertain, we believe they, in general, are close to reality, considering that the uncertainties may equalize each other.

The UK study [20] concludes with 326 million to 17 billion fragments of microplastics from the UK fishery. It would be great to compare this to our calculations, but unfortunately, the size and weight of a fragment are undefinable. However, their measurements show the mass loss from haulers ranges from 12 μg to 1050 μg per meter hauled for new and 10-year-old ropes, respectively [20], indicating that older

Fishing gear	Calculated annual microplastics from the Norwegian fishery (tons)	Calculated annual microplastic from the global fishery (tons)
Danish seine	87	311
Bottom trawl	49.7	1 656
Gillnet	18.4	613
Longline	37.2	1 240
Crab pots	15.4	802
Total	207.7	4 622

Table 8.
Summary of the Norwegian and global microplastics generated from wear and tear on fishing gear.

ropes wear more quickly than new ones. Therefore, we calculated the mass loss per meter rope hauled based on our calculated mass loss in Norway for some gear components worn primarily due to the hauler. The results are shown in **Table 9**, indicating that for surface longlines our results are comparable to [20], whereas, for gillnets and crab pot ropes, we are possibly underestimating the wear. Another explanation is that the haulers used for crab pots and gillnets are of the drum types that are more gentle to the ropes than the ones tested by [20].

For Danish seine, we have a reasonable understanding of the number of vessels involved worldwide; hence, the total numbers are well founded. Also, the wear and tear from the Norwegian fleet are based on interviews with fishers backed up by measurements on worn-out ropes. Thus, the numbers presented for the Danish seine are probably the ones best founded.

For trawls, we only consider sea bottom trawls as these are the ones contributing the most to the pollution. We do not consider Shrimp trawls as the demanded information is more challenging to get, and these trawls do not have plastic parts in contact with the seafloor. Yet, dolly ropes and other protective ropes are dragged along the seafloor, contributing considerably to the total plastic pollution. Hence, we believe that the numbers we present for trawl pollution are highly underestimated. The microplastic pollution originating from dolly ropes and other protective ropes is undoubtedly a topic that needs further investigation. Also, we do not have numbers for the worldwide use of trawlers; this is also a field in which more research is needed.

For gillnets, we use average numbers for the number of nets per fisher. These are based on interviews with fishers but are still questionable as the fishing fleet is large, and there may be significant differences between fishermen. Further differences are introduced when we consider gillnet fishing worldwide. Fishers in many countries probably use other types of ropes than Norway, and the average number of nets is

	Annual mass loss (kg)	Total length (m)	Average hauls per year	Mass loss per meter hauling (μg)
Gillnet float line	4.13	5 500	50	15.0
Crab pot ropes	1 860	2 755 400	20	33.8
Surface longline	1 042	64 800	70	229.7

Table 9.
Calculated mass loss per meter hauling for some gear components.

tough to estimate. Hence, the amount of microplastics from global gillnet fishing is a very rough estimate, and better statistics on using gillnets globally are needed.

For pots, we split between snow crab and other types of pots due to the different operating modes. As for the other gears considered, there are many uncertainties in the parameters used for the calculations, with the percentage loss being the most dubious. However, the numbers for Norway are considered well founded. For the global loss, there are probably significant differences in how the fishery is performed, and the average amount of pots and ropes used varies from country to country. Therefore, our estimates for the global loss are highly uncertain, and more research is needed to establish more accurate numbers.

Also, the main uncertainty for longlining is establishing a correct number for the annual percentage loss. Our fishers have estimated this to be 8%, which may be correct but difficult to verify. We don't have information on the global number of vessels and the parameters for each type of line. Hence, our numbers for the global loss are based on loose assumptions. More research must be performed on the global use of longlines to get more accurate results.

9. Conclusions

Our results show that the number of microplastics originating from fisheries worldwide is 4 622 t, which is probably a conservative estimate. We omitted some gears, like ordinary seine, and we only considered the rockhopper gear for the trawl. Hence, dolly ropes and trawl mats are not included, and we believe they contribute significantly to the total amount. The number of microplastics from lost and abandoned fishing gear is estimated to be 45000 tons [23]. This number is almost 10 times higher than our calculation but can make sense since lost and abandoned gear are complete, not only fragments. If correct, this suggests that the effort should be put into avoiding such lost and abandoned gear. However, we believe that finding ways to reduce microplastic wear and tear from commercial fishing activities is an important task too.

Despite many uncertainties, our calculations and results can provide helpful information and are essential to highlight the topic of microplastics originating from ordinary fishing activities. Then, we believe future research will lead to more accurate numbers. Specifically, more research on the global use of longlines, gillnets, and crab pots is needed, and a better understanding of dolly ropes and trawl mats is essential since these components contribute significantly to the total pollution.

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Author details

Tore Syversen* and Grethe Lilleng
SINTEF Nord, Tromsø, Norway

*Address all correspondence to: tore.syversen@sintef.no

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