Minimising plastic in the Western Rock Lobster industry

Phase 1 – scope and identify

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Executive Summary

The Western Rock Lobster (WRL) industry has committed to examining plastics use throughout the supply chain. This project was to understand the types and volumes of plastics in the Western Rock Lobster (WRL) supply chain and to provide suggestions of some possible interventions that could form the basis of a Phase 2 interventions project.

This study commenced with defining the scope of the project which originally was to include the plastic use after vessel unload until the exit of product from the processors. This original scope was developed as a previous study (Bornt et al., 2023) had analysed the WRL on vessel plastics use. However, following discussions with the authors, this previous study had focused on equipment such as pots, ropes and floats, so other vessel plastic sources such as bait liners, icebags, gloves and management tags were not considered, so were included in this report. A literature review was also completed during the initial stages of the project to understand previous studies and findings, although it was clear such whole of supply chain plastics mapping in seafood industry supply chains was comparatively rare.

Data collection methods as approved by the Curtin University Human Research Ethics Committee (HREC) included interviews and data collection from four WRL processors. There were two phases of data collection. The first activity was a "walk the chain" activity in which all four processors participated and explained processes throughout the facility. The second data collection was a requested quantification of all plastics used. Two processors participated in this activity, so results were extrapolated based on the "walk the chain" information.

Supply chain maps and plastics input/output data collection were completed separately and combined for the three most common WRL product lines: live lobster; frozen whole lobster (cooked or green); and frozen tails/heads. Data were also collected for both pre-Covid and post-Covid markets as there was a market shift away from the "live" market after Covid and this change in percentage market share of the different product formats also impact plastics use.

On vessel plastics per annum loss for the whole fleet was estimated at 13, 224 kg per annum for the ropes, pots and floats (Bornt et al., 2023) and 11,477.5 kg of plastic use per annum from other items such as DPIRD management crate tags, Personal Protective Equipment (PPE) mainly gloves, bait lines, ice bags and some banding. Fisher interview data (Bornt et al., 2023) and other sources suggested that these ancillary plastics are disposed to landfill either pre or post the fishing trip.

In the processing factories and during the initial processing stage (i.e. before packaging) PPE (gloves, sleeve covers) total industry use was estimated at approximately 8,382.7 kg per year and plastic packaging from consumables used in the processing (e.g. banding for cartons, chemical containers, plastic bag wrapping) was estimated at approximately 3,711.4 kg per year. Excluding the equipment plastic as highlighted in the previous study by Bornt et al., (2023), total plastics from the combination of the on vessel and initial processing stages was therefore estimated to be 23,571.6 kg per annum (e.g. PPE gloves, sleeve covers, bait liners, packaging from consumables etc). These products are almost exclusively disposed of in general waste (i.e. landfill).

The highest volume of plastics is used at the packaging stage, estimated to total 205,021.4 kg per annum across live and frozen supply chains. Items include carton liners, pallet liners, shrink wraps, bandings, labels, packing tape, polystyrene eskies, and gel ice packs. The total and comparative volumes of each packaging plastic component will vary according to the product format share and this is detailed in the report. The disposal of these plastics products is under the control of the end-users and final markets for the WRL packaged product.

A series of recommendations for seeking alternatives for the current plastic use are highlighted in the report as possible case studies for a Phase 2 interventions project. These recommendations include (but are not restricted to):

- alternate construction materials (e.g. wood; metal) or the use of marine biodegradable plastics for fishing equipment
- reconsidering bait supply and packaging strategies
- investigating alternate composition or omission of liners and other wrapping materials
- investigating alternate esky material
- changing the strategies for use of gloves and other PPE
- investigating alternatives to gel ice packs
- considering procurement from equipment suppliers with enhanced plastic management strategies.

Communication strategies with internal staff at processors and WRL members is also suggested. These recommendations are considered with preliminary attention to achievable time-lines, and regulatory, operational and economic factors. Another consideration for the priority areas is the current and future disposal options. In particular, disposal of much of the packaging waste, even with plastic reduction intervention strategies, cannot be controlled by WRL and aligned processors, as it is under the control of the final markets and end-users. Whole of chain communication strategies can therefore also be considered as part of a Phase 2 interventions project.

Some preliminary work has already commenced on the recommended Phase 2 intervention actions.

- Discussion has been commenced with packaging companies and manufacturers about supplying alternative recyclable and/or reusable cartons/eskies and compostable liners. Aligned packaging trials have commenced. This work aligns with similar sustainable packaging work currently being conducted with prawns and finfish at Curtin University.
- Plastic components of pots (tags/necks/float savers) have been sent to a NZ plastics manufacturing company for assessment of feasibility to construct these components using marine biodegradable alternatives.
- A “better bait” proposal to investigate recyclable/re-useable and compostable materials for bait supply packaging has been developed with a local company.

Extension of the project results has commenced with the WRL processors and will continue aligned with the development of the Phase 2 project. A summary powerpoint presentation with notes has been prepared to underpin extension activities.

It is considered feasible that the methodology developed in this project could be transferred to other seafood sectors considering a similar scoping investigation on plastics use through the supply chain.

1.Introduction

1.1 Background

The use of plastic in the Western Rock Lobster (WRL) industry has long been discussed, with the subject gaining increased attention following the 2019 national seafood industry conference, Seafood Directions. During this conference, one of the key topics was plastics. It was noted at the conference that: "Every year around 8 million metric tonnes of plastic are dumped into the ocean with an estimated 2/3 of the world's fish stocks suffering from plastic ingestion. If we continue on this trajectory, it is estimated that within the next decade there will be more plastic in the ocean than fish. Microplastics are affecting our aquatic ecosystems and threatening the human food chain. The seafood industry is directly dependent on the health of the marine environment and sustainable fish stocks. Reducing the use of plastic within industry and diverting plastic from landfill strengthens our commitment to environmental responsibility, increases our contribution to protecting the future of global fishery resources, and improves our social license to operate. There are leaders in industry demonstrating some unique innovation in this space and we need to encourage them to share their story and develop an industry action plan to curb the use of plastics."

At the WRL Board meeting in 2019 the WRL Board therefore highlighted the use of plastic as a potential risk to the WRL industry and advised that WRL should look to reduce the use of plastic within the industry. This project, FRDC 2020:062 Minimising plastic in the Western Rock Lobster (WRL) industry (Phase 1 – scope and identify) was developed as a response to that advice.

1.2 Need

In 2019 it was noted that: "Recent studies have estimated that approximately eight million tonnes of plastic end up in the world's oceans every year. This contributes to the deaths of the marine animals that become entangled. Plastic can also find its way into the stomachs of seabirds, sea mammals, fish and other marine life, affecting the entire food chain. The attributes of plastic that make it so attractive as a material, including its durability, are also the attributes that make it so dangerous and long-lived. Products might break down, but the plastic itself remains in the environment. Greenpeace researchers have found plastics in water and snow samples in areas as remote as Antarctica. CSIRO research has identified that almost three-quarters of the rubbish on Australia's coastline is plastic, and that it comes from Australian sources. Research from the Australian Institute of Marine Science has also reported widespread microplastic contamination of waters in north-western Australia. More recently, a study of juvenile Coral Trout from the Great Barrier Reef has identified that tropical fish are ingesting both plastic and non-plastic marine micro debris (particles of less than five millimeters)." (in FISH Magazine Volume 27-1).

WRL's vision (as outlined in its Strategic Plan 2018-2021) is to be an iconic global leader in sustainable fisheries management, with one of its strategic objectives to ensure long term access to the sustainable resource. WRL continually strives to improve its sustainability practices for the WRL industry, with the ability to transfer to and assist other fisheries being particularly attractive.

The research developed through this project will allow greater knowledge and understanding of:

- How and where plastic is used within the WRL industry; and
- Preliminary suggestions of viable (operational and economic) alternatives to the plastics currently in use.

The outputs of this project were intended to form the basis of a Phase 2 Project, which will allow for the development, trial and implementation of plastic alternatives, ultimately leading to a more sustainable fishery and contribute to WRL's vision of global leadership in sustainable fisheries management.

2. Objectives

The objectives of the project were:

- Identify where and why plastic is used in the Western Rock Lobster industry.
- Identify viable environmentally friendly plastic alternatives.

3. Methods

3.1 Scope

In collaboration with WRL staff, our approach involved establishing a small project working group. This group played a role in identifying and contacting key stakeholders across the supply chain. As well the group assisted in defining the scope of data collection in the WRL supply chain. A consideration was whether the scope should extend to end-users, such as retail and food service, and the exploration of both domestic and export markets. Identification of the key parameters to be covered in the mapping was also to be agreed.

The development of a human research ethics application and aligned paperwork is an important part of the consultative methodology. The submission of the application for approval was facilitated through the Human Research Ethics Committee (HREC) at Curtin University.

3.2 Literature review

A review of literature including academic and commercial publications generally on plastics; certification and packaging background and on aligned studies on plastics mapping in the fishing industry was undertaken.

3.3 Walk-the-chain

Collaborating closely with WRL staff to provide introductions, the "Walk-the-chain" approach aimed to gain practical insights into the specific WRL supply chains. The activity was conducted with four WRL processors. Within the processing facilities, various WRL product supply chains were selected for detailed study, focusing on both the unloading and processing/distribution phases and tracking the movement of materials through the supply chain. Supply chain maps were produced to describe the various supply chains.

During the walkthrough, attention was focused on identifying locations where plastics were produced along the chain. This encompassed not only the manufacturing facilities but also areas where plastics were utilized, packages and, potentially discarded. By identifying these points, the aim was to map the specific stages where interventions may be most effective. To complement observational data, key personnel at the processors and end-users were interviewed. These discussions were centered around where they see the barriers and opportunities for plastics replacement with a specific emphasis on packaging and aligned plastic materials.

3.4 Quantify Plastics Use

In order to assess the extent of plastic usage, volumes of plastic waste produced at each stage of the supply chain were quantified. Detailed data collection tables were supplied to the processors for inputting the required data.

3.5 Identification of Interventions

Following the mapping and quantification processes, there was identification in the supply chain where there was potential for interventions to reduce plastic use. Interventions were suggested and preliminarily assessed for impact on plastics volumes and considering economic, operational, and regulatory feasibility of replacing plastic items with alternates.

3.6 Recommendations, Outputs, Outcomes

Following the completion of the plastics mapping and quantification, the project will transition to advise on possible interventions and their potential impact on the baseline plastics mapping. This advisory stage would encompass preliminary technological, logistical, economic, and legislative considerations/impact to inform targeted actions for reducing plastic usage. An Extension of outputs will involve in-depth consultation with the industry stakeholders on key research outputs. This report will serve as a foundation for the subsequent phases of the project.

STOP/GO Point for Phase 2: At the conclusion of Phase 1 (this report), a critical decision point will be reached to determine the feasibility and potential impact of further investigation, commercial manufacture and implementation of interventions. The STOP/GO point will be guided by the project working group agreed evaluation (technical, logistical, economic and legislative) of the interventions. A decision will then be made on a possible Phase 2 application to undertake detailed investigation of some of the suggested interventions.

3.7 Extension

Extension of project results to the processors and WRL stakeholders was undertaken in meetings and written communication.

4. Results and Discussion

4.1 Scope

This study commenced with defining the scope of the project which originally was to include the plastic use after vessel unload until the exit of product from the processors. This original scope was developed as a previous study (Bornt et al., 2023) had analysed the WRL on vessel plastics use. However, following discussions with the authors, this previous study had focused on equipment such as pots, ropes and floats, so other vessel plastic sources such as bait liners, icebags, gloves and management tags were thereafter included in this report.

The discussion also led to an agreement to collaborate on both studies. This collaboration involves proposing interventions at both vessel and processing stages to be included in the findings of the current report.

Ethics Approved: Curtin HREC Ethics approval for interviews was granted (HRE2023-0280). Submitted documentation included information form; consent form; interview guide; data management plan and research integrity certification. Relevant Ethics documentation is attached as Appendix 1.

4.2 Literature Review

A literature review was completed to provide informed background to the project. This literature review can be found in Appendix 2.

This literature review resulted in a previous plastics mapping method developed in a New Zealand finfish case study (from Croft, F. & Farrelly. T. (2021)) being supplied to WRL for consideration for use in this study.

This method was approved for use by WRL with some modifications as listed below:

- The draft final and final reports must include Bornt et al., (2023) research outputs appropriately so that we have one single view of the whole supply chain's plastic use from catch to leaving the processing plant.
- We need **quantitative** data as these numbers will help WRL determine what alternatives are feasible to trial in phase 2 (e.g., if a small amount of plastic could be replaced by a fancy new technology, would it be feasible?). We would not want to return in Phase 2 to get quantitative data to inform feasibility decisions.
- The results of the work should also provide business reasons why the industry uses the different plastics that they use. For example, lightweight (reduces transport costs and WHS risks), durable (reduces replacement costs), etc.
- Regarding the mapping diagram, the plastics that processors input into the lobster supply chain must be diagrammed (e.g. plastic that comes into the chain via bait supplied to fishers by the processors, ice supplied to fishers etc.)

As a result of these suggested modifications collaboration has been ongoing with the University of Western Australia (UWA) (Katrina Bornt) /Department of Primary Industries and Regional Development (DPIRD) researchers (Jason How, Simon de Lestang) who had conducted and published results on the vessel plastics.

4.3 Walk the Chain

WRL facilitated e-introductions with processors, and interviews and supply chain mapping were commenced. Interviews were successfully conducted with the four major WRL processors.

Following these interviews, diagrammatic preliminary supply chain maps were developed for three WRL product lines: live lobster, frozen whole (cooked or green) lobster, frozen tails/heads. Each supply chain map includes a listing of plastics inputs/outputs associated with the respective product line (see Figures 1-3).

The subsequent sections provide a more detailed discussion of each distinct supply chain. A separate discussion focused on consumables used by the industry. This included bait packaging, typically supplied by the processors. Other consumables were Personal Protective Equipment (PPE) (on vessel and in processing facility) and other supporting consumables (e.g. packaging, chemical containers etc.).

4.3.1 Live Lobster Supply Chain

Figure 1 describes the live Rock Lobster Supply Chain and further description is provided below.

- The product is packed from the boat in plastic crates and transported to the processing facility. Wooden and plastic pallets may be used at unload, with a preference for wooden pallets due to their durability.
- Crates are unloaded at the processing facility and transported inside. DPIRD- supplied plastic crate tags are removed and the product is placed in live holding tanks.
- Live products are transferred to polystyrene eskies with wood chips. Ice packs may or may not be added.
- Eskies are sealed with plastic tape, and labels are affixed.
- Eskies are stacked on pallets which may or may not be shrink wrapped before transport.

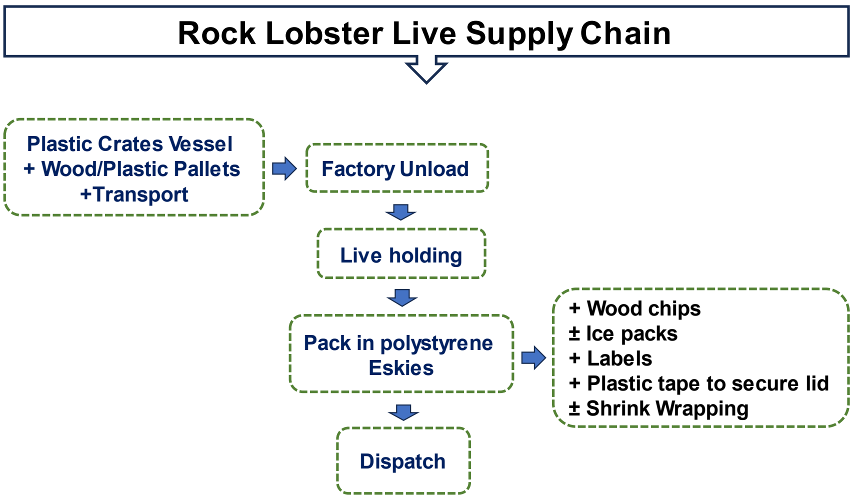

Figure 1: Maps illustrating specific stages of 3 selected Western Rock Lobster (WRL) supply chains, highlighting areas of plastic use. =/- sign signifies that the use of that plastics component is variable between operations

4.3.2 Frozen Whole (Cooked or Raw) Lobster Supply Chain

Figure 2 describes the Individual Frozen Whole Rock Lobster Chain and further description is provided below.

- The product is packed from the boat in plastic crates and transported to the processing facility. Wooden and plastic pallets may be used at unload with a preference for wooden pallets due to their durability.
- Crates are unloaded at the processing facility and transported inside. DPIRD supplied plastic crate tags are removed.
- The product is processed in tanks with addition of preservatives. Plastic containers containing preservatives may or may not be recycled to suppliers.
- The product may or may not be cooked.
- The product is packed in cardboard cartons (with or without waxing).
- Individual wrapping may or may not be applied, depending on market requirements, wrapping materials such as plastic suitable for thermoforming individual plastic bags, or cellophane bags are used.
- Single use liners of various thickness may or may not be included in the cartons depending on market and freight regulations.
- Ice packs may or may not be added.
- Labels are added to the cartons (material varies) and cartons are packed on pallets.
- Pallet liners between carton layers may or may not be included.
- Cartons may be banded together and/or shrink wrapped for transport.

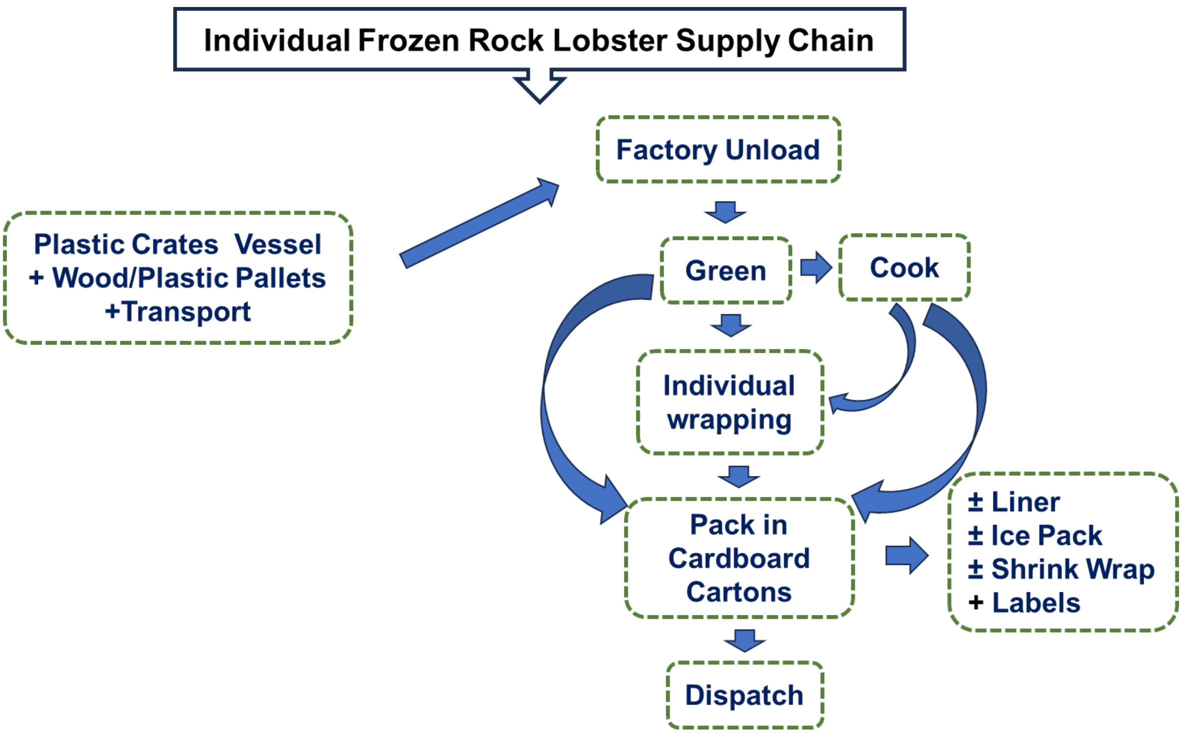

Figure 2: Map illustrating the individual frozen Western Rock Lobster (WRL) supply chain, highlighting areas of plastic use. =/- sign signifies that the use of that plastics component is variable between operations

4.3.3 Frozen Lobster Tails/Heads Supply Chain

Figure 3 describes the Individual Frozen Tails/Heads Rock Lobster Chain and further description is provided below.

- The product is packed from the boat in plastic crates and transported to the processing facility. Wooden and plastic pallets may be used at unload, with a preference for wooden pallets.
- Crates are unloaded at the processing facility and transported inside. DPIRD supplied plastic crate tags are removed.
- The product is processed in tanks with addition of preservatives. Plastic containers containing preservatives may or may not be recycled to suppliers.
- The product is processed into frozen tails and heads.
- The product is packed in cardboard cartons (with or without waxing).
- Tails may or may not be individually wrapped, depending on market requirements, using materials such as plastics suitable for thermoforming, individual plastic bags or cellophane. Heads are never individually wrapped.
- Single use liners of various thicknesses may or may not be included in the carton depending on market and freight regulations.
- Ice packs may or may not be added.
- Labels are added to the cartons (material varies) and cartons are packed on pallets.
- Pallet liners between carton layers may or may not be included.
- Cartons may be banded together and/or shrink wrapped for transport.

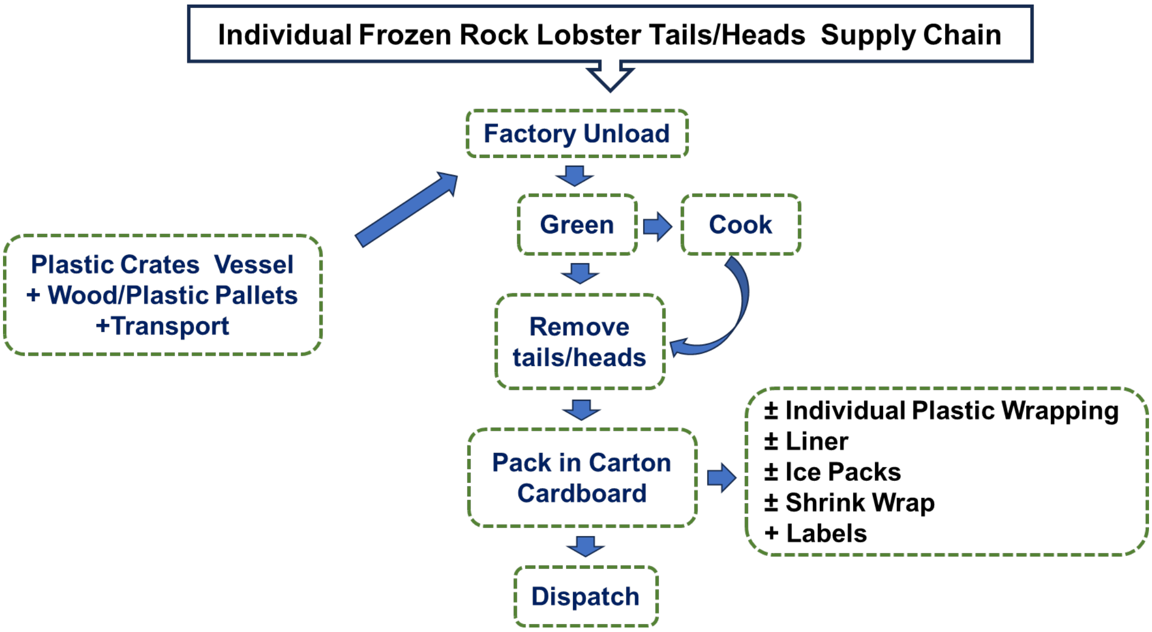

Figure 3: Map illustrating individual frozen heads and tails Western Rock Lobster (WRL) supply chain, highlighting areas of plastic use. =/- sign signifies that the use of that plastics component is variable between operations

4.3.4 Personal Protective Equipment (PPE) and other Consumables

PPE's (processing)

- Consumable equipment used during processing lines (e.g. gloves, liners, aprons, shrink plastic etc.)
- Gloves (four types from single use to washable) with staff instructions/inductions may be applied for glove use. The company may wash re-useable gloves for staff.
- Aprons (single use or reusable).
- Sleeve liners (daily for 4-5 hours).
- Hairnets and beard nets, not plastic.

Packaging from Consumables Supply (processing)

- Detergents/Chemicals (already collected and recycled by suppliers).
- Wrapping around bulk packaging materials (eskies/cardboard/cartons/tape) processing equipment.

On Vessel Fishing Consumables

It is noteworthy that there are currently 234 vessels operating in the WRL fishery. Harvest equipment plastics volumes were reported in Bornt et al., (2023) and are discussed later in this report. Bornt et al., (2023) states that previously it had been reported that the most dominant oceanic fishing debris from surveys in early 2000's was rope, plastic bait wrapping, and plastic packaging bands from bait boxes. However, possession of plastic packaging bands "at sea" has been prohibited in Western Australia since 2011.

Other forms of plastics used onboard the vessel and quantified in this study include:

- Bait in cardboard packaging supplied by processors with no strapping but with single use liners. This is generally discarded before or after fishing.
- Ice packaging plastic for vessels. This is generally discarded before or after fishing.
- Gloves and other PPE.

4.4 Quantification of Plastics Usage

The preliminary "walk the chain" analysis highlighted that various processing supply chains and product formats utilise different volumes and types of plastics. Consequently, market information, specifically regarding product format market shares as a percentage were requested from WRL. It was also decided to consider pre- and post- Covid production, given the significant shifts in market share during this period. The collected data will allow assessment of the impact of the changing percentage share of different product types before and after Covid on the plastics volumes. Economic data has also been received from the WRL Council for approximate processing share percentage by company to allow the plastics audit and quantification to encompass an analysis of the diverse plastics use practices observed across different companies. Whole of industry extrapolation could then be made more reasonable.

For the land-based processing operations, data tables were developed for plastic items for each supply chain (live; whole (raw and cooked); tails/heads) and for each item the volume; outcome; make (to work out the composition) and other information was requested. Tables were developed to itemise consumable equipment used during processing lines (e.g. gloves; liners; aprons; shrink plastic etc) and to itemise plastics associated with incoming (e.g. packages for gloves; chemicals; etc.) and outgoing (e.g. eskies; tape; labels etc.) supply items. At this stage the long-term plastic items in the processing factory (e.g. tanks; pallets (when plastic not wooden)) were not included in the data analysis.

4.4.1 Economic Information

Market share for WRL processors (WRL estimates).

The market share for the land based distribution and/or processing sector has been estimated at Geraldton Fishermans Co-operative; 60-70%; Indian Ocean Rock Lobster: 10-12%; Kailis Brothers: 10-12% and Bluwave seafood 8-10%. Other Operations are estimated to total 5% or less.

Product format Percentages: Pre and Post Covid (WRL estimates).

To facilitate supply chain mapping, WRL provided the following estimates, acknowledging the necessity of figures for both pre and post Covid periods due to market changes.

Table 1: Estimates of Market Share for the Different Product Lines.

Australian Statistics (ABS export statistics):

PRODUCT	PRE COVID (2018-19)	POST COVID (2022/23)
AUSTRALIA		
Live and fresh	97%	87% of exports with a declining trend (83% in 2023)
Frozen whole	<1%	Frozen whole raw increasing trend 9% in 2023, cooked frozen whole increasing trend to 5% in 2023.
Tails	~2%	2-4%
WESTERN AUSTRALIA		
Live and fresh	~97%	70.3%
Frozen whole	<1%	5.7% whole raw,16.4% whole cooked
Tails	~2%	7.4%

These market share results underpinned extrapolated plastics quantification data in Tables 2 (2018-19) and 3 (2022-23) and Figures 7 (2018-19) and 8 (2021-23) to try and understand the impact of the changed product market share of the different products on the plastics use.

4.4.2 Plastics Quantification Results

On Vessel Equipment

Bornt et al., (2023) studied plastic and other gear loss from vessels in the WRL fishery. The article reported that the estimated annual percentage of gear lost (10.8%) and rate of “active” gear loss by fishing effort (0.2%) were lower than global estimates for other pot fisheries, indicating that plastic gear loss from this commercial fishery is relatively low. Plastic gear loss was attributed to rope (47.0%), pot components (30.7%), and floats (22.3%), of which 78.0% were polypropylene and polyethylene. It was reported that the composition of pots, measures used to prevent gear loss, and changes to management could influence plastic gear loss from this fishery.

According to Bornt et al., (2023) the estimated median weight of all plastics lost from vessel gear loss by the WRL fishery annually was 13, 224.3 kg. This loss consisted of pot necks (961 kg), bait lids (850.3 kg), bait baskets (2184 kg); shock cord (62.5 kg), rope (6213.2 kg), EPS Floats (2853.3 kg) and float savers (100 kg). This data is not included in the quantification below, but interventions are suggested in later sections.

The data table was distributed to the four major WRL processors and two detailed processor responses were received. The other two processors did not follow up with data after repeated requests.

From these figures and the interview data, the following maps and data sets were developed (Figures 4-8 and Tables 2-4). It is noteworthy that to date, as mentioned previously in the methods section, audit volume estimates of plastics for 2022-23 have been extrapolated from the data provided by two processors. This was despite repeated follow ups for data from the other two processors following the initial walk the chain activity. Together, these two processors represent approximately 22% of total industry production volumes. This low percentage means that this processing stage data must be interpreted with knowledge of the limitations. Excel spreadsheets have been developed to allow any such data adjustment should data be supplied later.

This limitation is somewhat reduced due to the detailed information gathered during the initial 'walk the chain' phase with all processors. This information has informed the assumptions and estimates of plastic use particularly when actual volumetric data collection was not supported. Therefore we believe that the data estimate/extrapolations are credible.

Additionally, data concerning industry-wide common plastic usage (e.g. plastic glove, bait packaging etc.) at the harvest stage (i.e. by fishers) was assisted by additional information gathered in the study conducted by Bornt et al., (2023).

Based on the data collected:

- Plastic volumes at the vessel/harvest stage encompassing ropes, floats, and pot equipment (totaling 13, 224 kg of plastic lost per annum across the fishery) was previously reported (Bornt et al., 2023). Additional vessel plastics volumes as described in this study was estimated to be 11,477.5 kg per year. Items included in this volume include DPIRD management crate tags, PPE gloves and bait liners. Fisher and processor interview data suggests that these plastics are disposed to landfill either pre or post fishing trip.
- At the initial processing stage (prior to packing), plastic usage can be categorised as PPE (gloves, sleeve covers), estimated at approximately 8,382.7 kg per year and plastic packaging from consumables used in the processing (e.g. banding for cartons, chemical containers, plastic bag wrapping), estimated at approximately 3,711.4 kg per year.
- Total plastics from the combination of the on vessel data (excluding ropes, pots and floats) and initial processing stages, was therefore estimated to be 23,571.6 kg per annum. This plastic is almost exclusively disposed of in general waste (i.e. landfill).
- The highest volume of plastics is used at the packing stage. In the 2022/2023 post Covid estimates, the volume was estimated to total 205,021.4 kg per year across live and frozen supply chains. Items include individual lobster wrapping, carton liners, pallet liners, shrink

wrapping around pallets, bandings for cartons on pallets, labels, carton sealing tape, polystyrene eskies, and gel ice packs. In 2022/2023 the live lobster supply chain was estimated to consume the most plastic packaging (116,512.1 kg), followed by the frozen whole supply chain (71,216.7 kg), and frozen tails supply chain (17,292.6 kg). These packaging plastics are disposed of by either customers or end-consumers in target domestic and overseas markets.
- At the post Covid (2022/2023) packing stage, the highest volume of plastics is estimated to arise from use of polystyrene eskies (89,588.0 kg) across all three supply chains. Individual plastic wrap packaging (45,910.2 kg) used for frozen products and gel ice packs used for live products (34,024.7 kg) also generate materially high levels of plastic usage.
- In 2022/2023 total plastic usage across the whole industry, from harvest to packing stages, excluding the catching equipment plastics as itemised by Bornt et al., (2023), was estimated at 228,593.1 kg per year.

Although additional data will improve reliability of the audit volume estimates, these preliminary figures and plastic flows have been mapped in three supply chain maps (Figures 4, 5 and 6) to show the breakdown of plastic usage between live, frozen whole, and frozen tail products. Audit volume estimates for 2022-23 are also presented in Table 2. A heat map has been applied to Table 2 to indicate areas where plastic usage and disposal are highest.

Notably, the concentration of plastic use across the three supply chains (live, frozen whole, frozen tails) did change significantly in post-COVID years (2022/23 compared to 2018/19) primarily owing to reduced live exports which was aligned with an increase in frozen export categories. Hence the 2018/19 estimate of plastic use when live product was predominant (see Table 1) was 264,269kg pa whereas the 2022/23 estimates (when there was a greater volume of frozen product was 228,593kg. A heat map has been applied to Table 3 to indicate areas where plastic usage and disposal were highest in 2018/19. The ‘hotspots’ contrast those of Table 2 (2022/2023), in particular, the volumes from individual wrap packaging, carton liners, and banding increased with the larger proportion of frozen product.

These changes align with the change in supply and demand for live exports versus frozen exports. It should be noted that overall, industry plastic use decreased by approximately 14% between 2018/19 and 2022/23 in line with the decrease in total industry production volumes but this was not correlated with the changes in concentration of plastic use that was estimated at the individual supply chain-level. For example, a 48% (2,685 tonnes) reduction in live exports from 2018/19 to 2022/23 was correlated with a 45% (94 tonnes) decrease in plastic use in that particular supply chain. However, these changes were off-set by a significant thousand-fold increase (916 tonnes) in frozen whole lobster exports, which was correlated with a 262% increase (71 tonnes) in plastic use in that supply chain.

These and other changes in plastic use between the study years are illustrated in the contrasting graphs in Figures 7 and 8. Altogether the changes suggest that market forces and forecasting should also be considered in the development of management changes or interventions for plastic use.

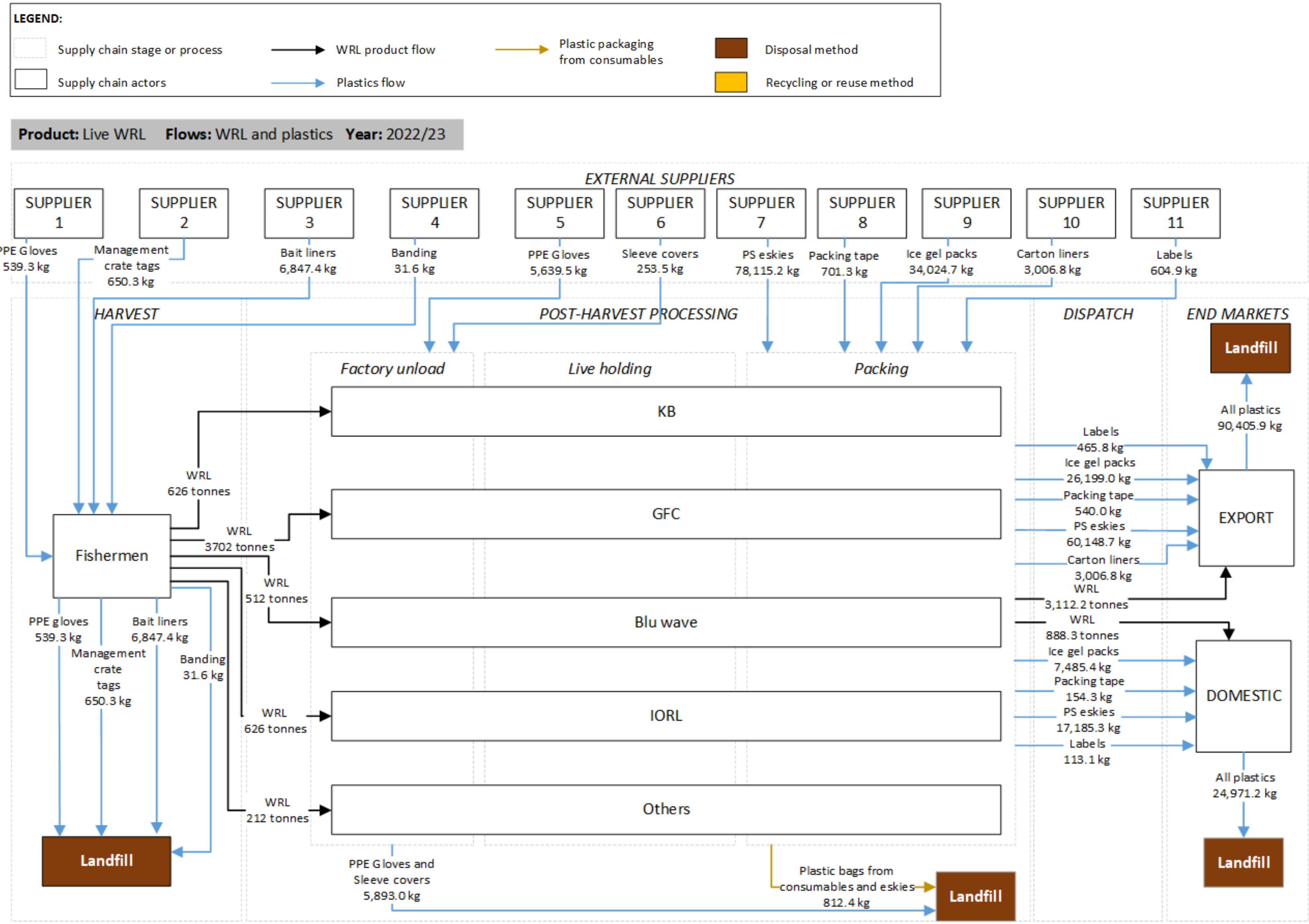

FIGURE 4. ESTIMATED PLASTIC FLOWS IN THE LIVE WESTERN ROCK LOBSTER SUPPLY CHAIN, 2022-23.

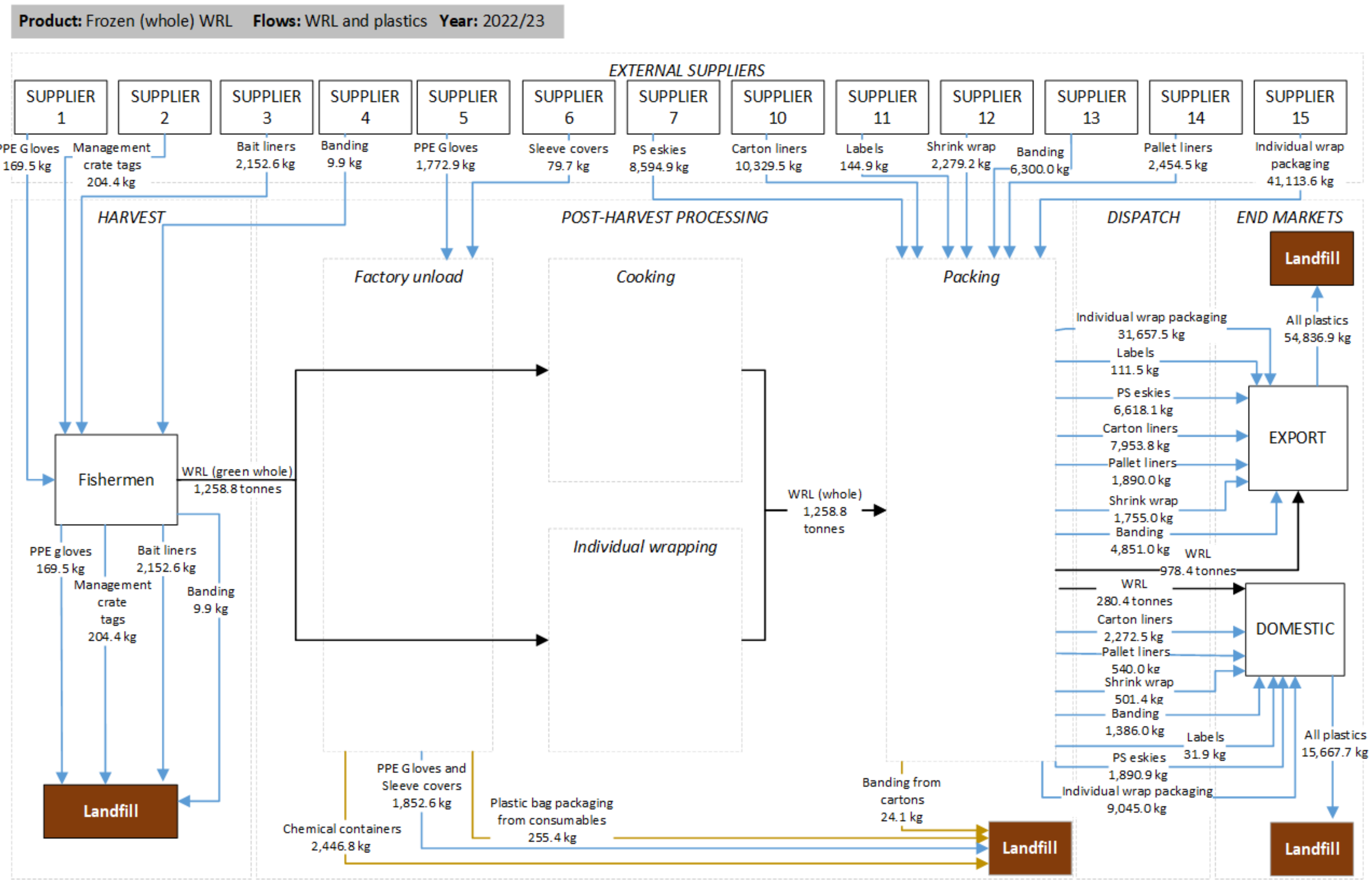

FIGURE 5. ESTIMATED PLASTIC FLOWS IN THE FROZEN WHOLE WESTERN ROCK LOBSTER SUPPLY CHAIN, 2022-23.

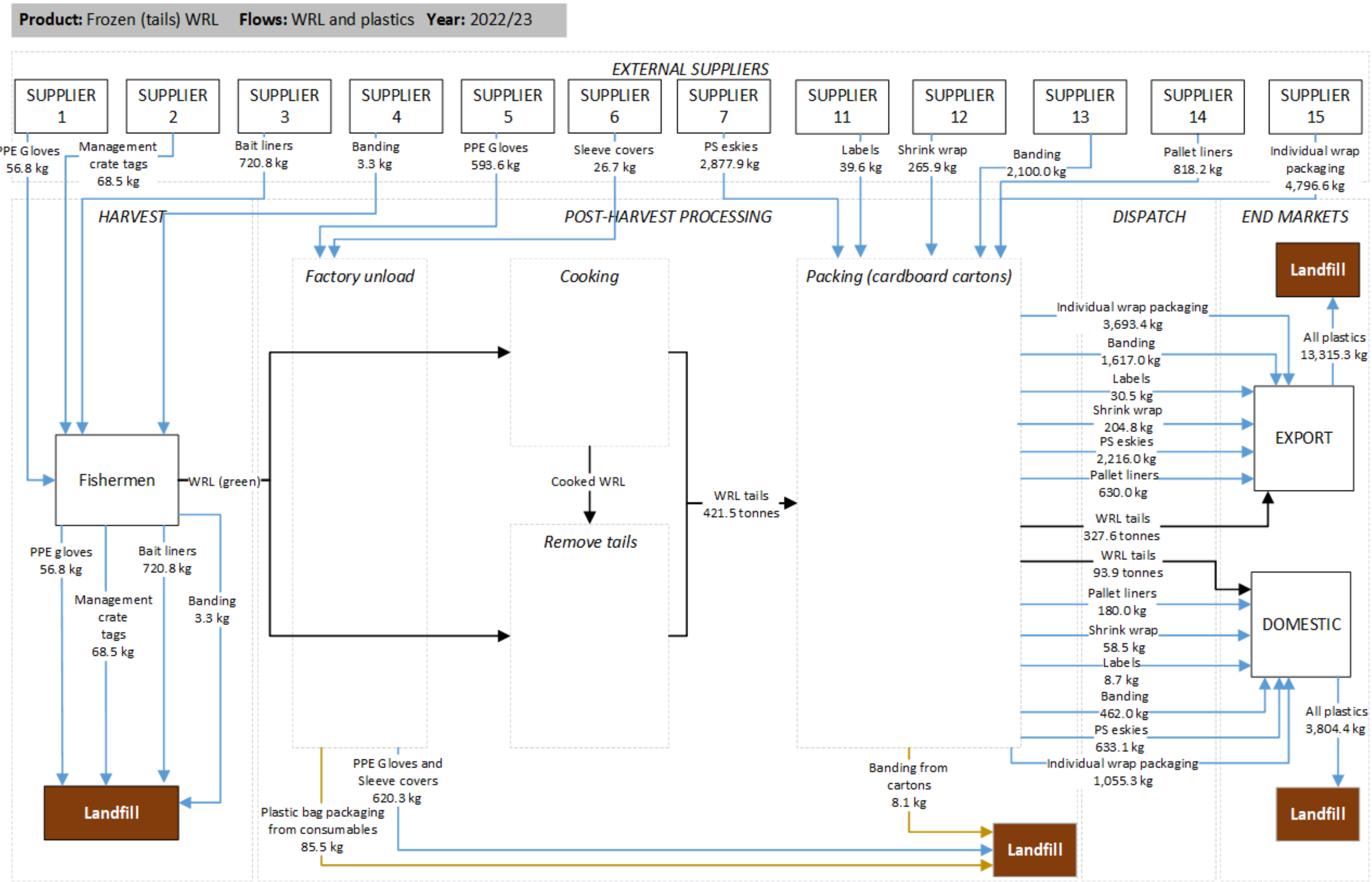

FIGURE 6. ESTIMATED PLASTIC FLOWS IN THE WESTERN ROCK LOBSTER FROZEN TAILS SUPPLY CHAIN, 2022-23.

TABLE 2. AUDIT VOLUME ESTIMATES OF PLASTIC USAGE AND DISPOSAL, 2022-23.

	Post-COVID Plastics per annum (2022-23, kg)																	
	Crate tags	Gloves		Sleeve covers	Aprons	Liners			Cartons/ PS Eskies	Shrink wrap (pallet)	Individual wrap packaging	Banding	Label	Tape	Gel ice packs	Chemical containers	Plastic bags	Total Plastics
Processing Stage		Single use	Multiple use			Bait Liners	Carton Liners	Pallet Liners										
Stage 1: Vessels/Harvest																		
Management	925.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	925.1
PPE	-	767.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	767.1
Crates	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bait and ice packaging	-	-	-	-	-	9,740.3	-	-	-	-	-	45.0	-	-	-	-	-	9,785.3
Subtotal Stage 1	925.1	767.1	-	-	-	9,740.3	-	-	-	-	-	45.0	-	-	-	-	-	11,477.5
Stage 2: Processing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PPE	-	187.0	7,835.1	360.6	-	-	-	-	-	-	-	-	-	-	-	-	-	8,382.7
Packaging from incoming supply	-	-	-	-	-	-	-	-	-	-	-	109.1	-	-	-	2,446.8	1,155.6	3,711.4
Subtotal Stage 2	-	187.0	7,835.1	360.6	-	-	-	-	-	-	-	109.1	-	-	-	2,446.8	1,155.6	12,094.1
Stage 3: Packaging/Distribution																		
Live products	-	-	-	-	-	-	3,006.8	-	78,115.2	59.3	-	-	604.9	701.3	34,024.7	-	-	116,512.1
Frozen whole products	-	-	-	-	-	-	10,329.5	2,454.5	8,594.9	2,279.2	41,113.6	6,300.0	144.9	-	-	-	-	71,216.7
Frozen head/tail products	-	-	-	-	-	-	6,394.5	818.2	2,877.9	265.9	4,796.6	2,100.0	39.6	-	-	-	-	17,292.6
Subtotal Stage 3	-	-	-	-	-	-	19,730.8	3,272.7	89,588.0	2,604.4	45,910.2	8,400.0	789.3	701.3	34,024.7	-	-	205,021.4
Total across all stages	**925.1**	**954.2**	**7,835.1**	**360.6**	**-**	**9,740.3**	**19,730.8**	**3,272.7**	**89,588.0**	**2,604.4**	**45,910.2**	**8,554.1**	**789.3**	**701.3**	**34,024.7**	**2,446.8**	**1,155.6**	**228,593.1**

TABLE 3. AUDIT VOLUME ESTIMATES OF PLASTIC USAGE AND DISPOSAL, 2018-19.

	Pre-COVID Plastics per annum (2018-19, kg)																	
	Crate tags	Gloves		Sleeve covers	Aprons	Liners			Cartons/ PS Eskies	Shrink wrap (pallet)	Individual wrap packaging	Banding	Label	Tape	Gel ice packs	Chemical containers	Plastic bags	Total Plastics
Processing Stage		Single use	Multiple use			Bait Liners	Carton Liners	Pallet Liners										
Stage 1: Vessels/Harvest																		
Management	1,038.1	-		-			-		-	-		-	-	-	-			1,038.1
PPE	-	1,067.8		-			-		-	-		-	-	-	-			1,067.8
Crates																		-
Bait and ice packaging	-	-		-		13,557.6			-	-		62.6	-	-	-			13,620.2
Subtotal Stage 1	1,038.1	1,067.8		-		13,557.6	-		-	-		62.6	-	-	-			15,726.2
Stage 2: Processing																		
PPE	-	260.3	10,905.7	502.0			-		-	-		-	-	-	-			11,668.0
Packaging from incoming supply	-	-		-								12.4				124.2	1,608.5	1,745.2
Subtotal Stage 2	-	260.3	10,905.7	502.0	-	-	-	-	-	-	-	12.4	-	-	-	124.2	1,608.5	13,413.2
Stage 3: Packaging/Distribution																		
Live products	-	-		-			5,774.8	-	150,025.1	-		-	937.5	1,086.9	52,733.9			210,558.2
Frozen whole products							524.5	124.6	16,507.0	115.7	2,087.7	319.9	7.4					19,686.8
Frozen head/tail products							1,939.4	248.2	872.9	80.6	1,454.8	636.9	12.0					5,244.8
Subtotal Stage 3	-	-		-		-	8,238.7	372.8	167,405.0	196.4	3,542.4	956.8	956.8	1,086.9	52,733.9	-	-	235,489.9
Total across all stages	**1,038.1**	**1,328.1**	**10,905.7**	**502.0**	**-**	**13,557.6**	**8,238.7**	**372.8**	**167,405.0**	**196.4**	**3,542.4**	**1,031.9**	**956.8**	**1,086.9**	**52,733.9**	**124.2**	**1,608.5**	**264,629.2**

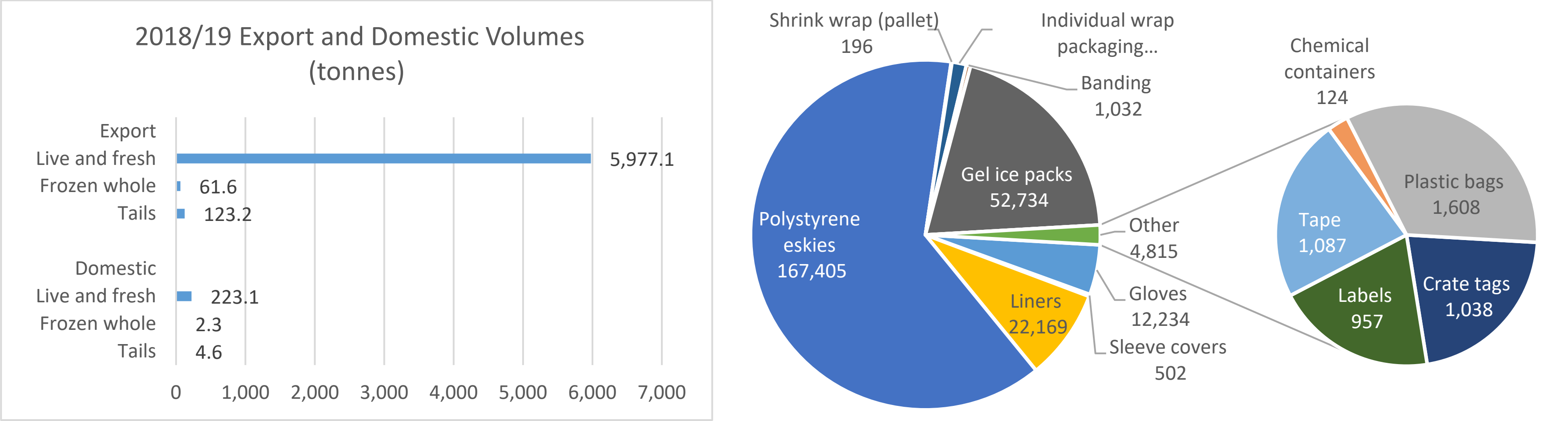

FIGURE 7. PRE-COVID (2018/19) EXPORT AND DOMESTIC FIGURES AND ASSOCIATED PLASTIC USAGE.

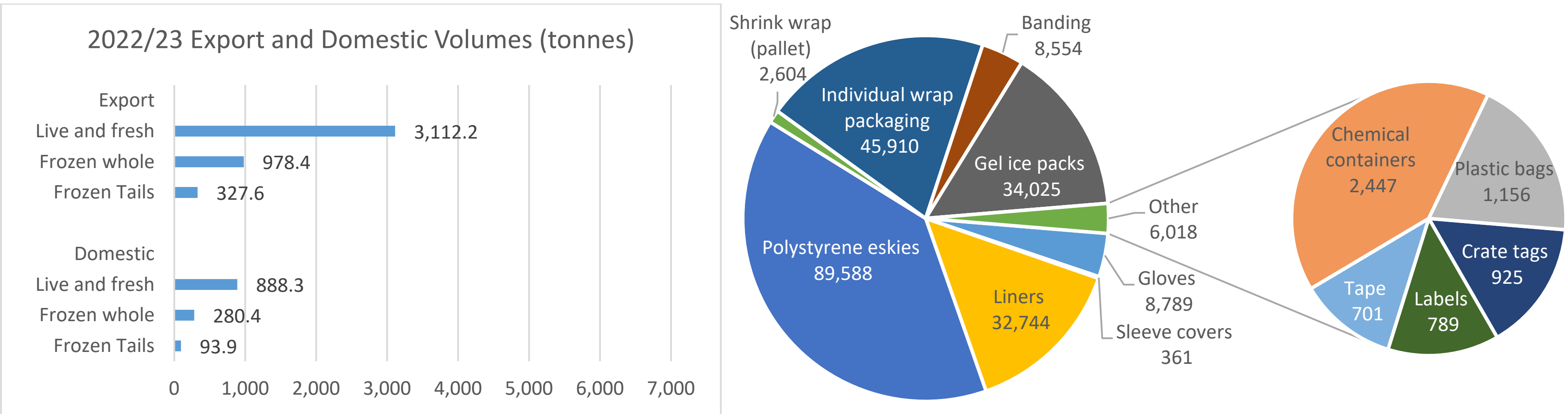

FIGURE 8. POST-COVID (2022/23) EXPORT AND DOMESTIC FIGURES AND ASSOCIATED PLASTIC USAGE.

4.5 Identification of potential interventions

Preliminary recommendations for interventions were made according to the Zero Waste Hierarchy (Figure 9).

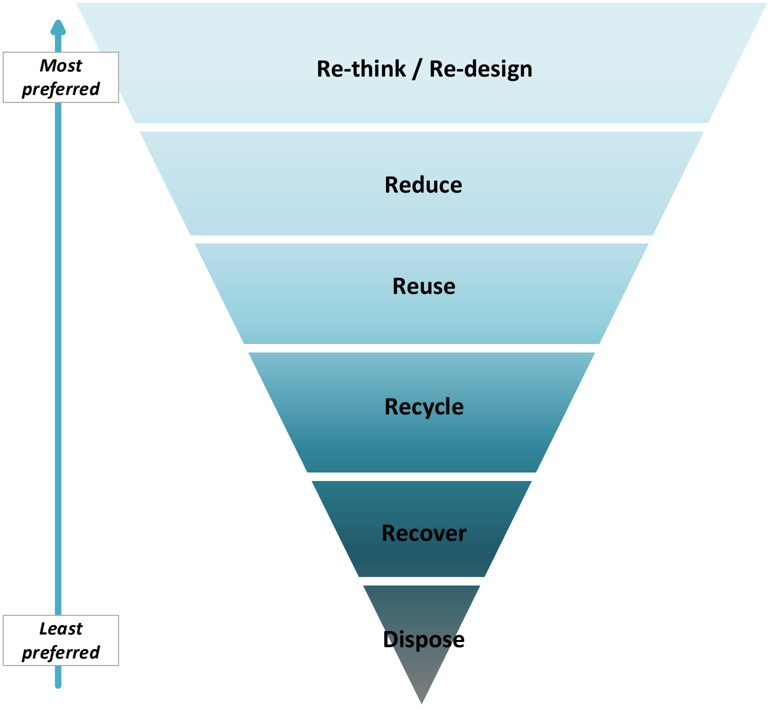

Figure 9. Zero Waste Management Hierarchy. Adapted from Ellen MacArthur Foundation (https://www.ellenmacarthurfoundation.org/circular-economy-diagram)

Table 4 (harvest equipment supplied by Bornt (pers comm) and Table 5 (on and off vessel) describes most of the plastics inputs/outputs from the WRL supply chain and includes a preliminary list of suggested interventions. The interventions have been categorised according to the Zero Waste Hierarchy (Figure 9) interventions.

Additionally, indicators have been used to suggest future actions required (i.e. new product development, seeking alternative existing products or designs, and supply chain management of either suppliers, customers, or regulators) and whether the suggested interventions can be implemented in the short-term (e.g. 1 year), medium-term (e.g. 3 years), or long-term (e.g. 5+ years). At this stage the hard plastic items in the processing factory with 10 year life spans (e.g. tanks; plastic pallets) have not been included.

Table 4. Preliminary Recommendations for Alternate Products (Harvest Equipment) (Bornt pers comm)

Key: NPD = new product development; Alt = alternative existing products; SCM = supply chain management

Plastic item / category	Polymer (if known)	Single-use (Y/N)	Current waste pathway	Potential environmental / social consequences?	Recommendations	Action			Projected Implementation Timeframe		
						NPD	Alt	SCM	Short-term	Medium-term	Long-term
Rope	Polypropylene / polyethylene / lead	N	Landfill / environment / reuse (recreational fishers & artists) (Bornt et al. in-prep)	6.21 t lost to ocean / y (Bornt et al., 2023) High presence on beaches (AMDI, 2020) Significant microplastic release when in use (Wright et al., 2021)	• Highest environmental and social risks of all fishing gear (Bornt et al., in-prep) • Currently no suitable plastic-free alternatives. • Significant R&D required. • Other strategies required (gear loss mitigation measures, improved maintenance schedules & waste management, consideration of circularity in design to improve reuse and recyclability potential) (Bornt et al., in-prep)	•*					•
Floats + float savers	Expanded polystyrene	N	Landfill / environment	2.85 t lost to ocean / y (Bornt et al., 2023) High presence on beaches (AMDI, 2020). Significant microplastic release (Huang et al., 2023).	• Potentially high environmental and social risks (Bornt et al., in-prep) • Currently no suitable plastic-free alternatives • Significant R&D required. • Concern over fragmentation of polystyrene • Other plastic float types (e.g. ethylene vinyl acetate; EVA) could release less microplastics when in use (Bornt et al., in-prep). • Other strategies required (gear loss mitigation measures, improved maintenance schedules & waste management, consideration of circularity in design to improve reuse and recyclability potential) (Bornt et al., in-prep)	•*					•

Bait baskets	Polypropylene	N	Landfill / environment	2.18 t lost to ocean / y (Bornt et al., 2023)	• Moderate environmental and social risks of all fishing gear (Bornt et al., in-prep) • Plastic lost with pot and present to public as beach litter (Bornt et al., in-prep). • Higher plastic contamination than pot necks and bait lids (Bornt et al., 2023). • Few fishers using metal alternatives; effort required to improve design (e.g. longevity, functionality) of metal (Bornt et al., in-prep).		•			•	
Pot necks	Polyethylene	N	Landfill / environment	0.96 t lost to ocean / y (Bornt et al., 2023)	• Least environmental and social risks of all fishing gear (Bornt et al., in-prep) • Plastic lost with pot and present to public as beach litter (Bornt et al., in-prep). • Wooden option available but requires ongoing maintenance (Bornt et al., in-prep). • Most economically viable plastic-free pot component to replace (Bornt et al., in-prep).		•		•		
Bait lids	Polypropylene	N	Landfill / environment	0.85 t lost to ocean / y (Bornt et al., 2023)	• Least environmental and social risks of all fishing gear (Bornt et al. in-prep) • Plastic lost with pot and present to public as beach litter (Bornt et al. in-prep). • Additional plastic lids lost from pots when in use (Bornt et al., 2023). • Most functional plastic-free pot component currently used (Bornt et al., 2023). • Can be self-manufactured to reduce economic cost (Bornt et al., in-prep). • Eliminate need for shock cord / bungee cable by designing other mechanisms that secure wooden lids and gates (Bornt et al., in-prep).		•		•		

***STRATEGIES OTHER THAN GEAR ALTERNATIVES**

TABLE 5. PRELIMINARY RECOMMENDATIONS FOR ALTERNATE PRODUCTS (OFF VESSEL)

Key: NPD = new product development; Alt = alternative existing products; SCM = supply chain management

Zero Waste Management Intervention	Plastic type	Total (kg)	Supply Chain Stage	Current Disposal	Recommendations	Action			Projected Implementation Timeframe		
						NPD	Alt	SCM	Short-term	Medium-term	Long-term
Re-think / Re-design	Crate tags	473.8	Vessels	Landfill	Investigate biodegradable materials, recyclable or re-useable tags		•				•
	Polystyrene eskies	125,203.6	Processing factory	At product destination	Investigation of alternates in progress, including Disruptive Packaging cartons, cardboard with Woolpack inserts, and chitofoam		•			•	
	Individual wrap packaging	87,818.2	Processing factory	At product destination	Consider requirement for individual wrapping – discussions with customers; investigate compostable or biodegradable packaging options; investigate packaging derived from chitosan from shell	•		•		•	
	Carton banding	1,383.2	Processing factory	At product destination	Consider recyclable paper-based strapping (e.g. A&A Packaging or Ecostrap brands)		•		•		
	Labels	1,829.7	Processing factory	At product destination	Consider switching to compostable or non-plastic alternatives, or printing directly onto cartons where possible		•		•		
	Packing tape	701.3	Processing factory	At product destination	Consider recyclable paper-based tape (e.g. Signet brand)		•		•		
	Gel ice packs	34,854.5	Processing factory	At product destination	Investigate dry ice as an alternative		•		•		
	Bait liners	9,740.3	Vessels	Landfill (before or	Remove bait liners from bait; compostable bait liners; consider						

Zero Waste Management Intervention	Plastic type	Total (kg)	Supply Chain Stage	Current Disposal	Recommendations	Action			Projected Implementation Timeframe		
						NPD	Alt	SCM	Short-term	Medium-term	Long-term
				after going to sea)	suppliers such as Mendolia Seafoods for biodegradable bait boxes						
	Ice bags	TBC	Vessels	Landfill (before or after going to sea)	Supplier discussion (procurement)			•			•
	Carton liners	38,103.9	Processing factory	At product destination	Consider using cartons that do not require liners (regulatory issues); compostable liners (e.g. Biobag brand)		•	•			•
Reduce	Pallet liners	3,272.7	Processing factory	At product destination	Investigate non-use or compostable alternatives		•		•		
	Shrink wrap	3,272.7	Processing factory		Reduce use (e.g. GFC no longer use pallet wrapping) which resulted in significant tonnage reduction		•		•		
	Plastic bags (incoming supplies)	1,155.6	Processing factory	Landfill	Supplier discussions to remove plastic (procurement)			•		•	
	Gloves	TBC	Vessels	Landfill	Investigate reusable, washable gloves		•		•		
	Disposable gloves	15,502.2	Processing factory	Landfill	Re-use till not fit for purpose (SOP for glove use developed in some processors); washable and re-used		•		•		
	Disposable sleeve covers	405.2	Processing factory	Landfill	Consider reusable sleeve protectors (e.g. milking sleeves)		•		•		
Reuse	Chemical containers	2,446.8	Processing factory	Landfill	Consider seeking suppliers that recycle containers			•		•	

5. Recommendations, Outputs and Outcomes

5.1: Recommendations

Recommendations for more detailed development of strategies to reduce plastic use in the WRL industry are summarised in Table 6 and Table 7. Recommendations are based on plastics volume, but there is also comment on other factors such as social licence considerations and operational, economic and regulatory feasibility. These recommendations can be further developed as potential case studies for a Phase 2 project. Another consideration for the priority areas is the current and future disposal options. In particular, disposal of much of the packaging wastes, even with plastic reduction intervention strategies, cannot be controlled by WRL and aligned processors, as it is under the control of the final markets and end-users. Whole of chain communication strategies could therefore also be considered as part of Phase 2.

Some preliminary work has already commenced on the recommended Phase 2 actions.

- Discussion has been commenced with packaging companies and plastics manufacturers about trialling commercial re-useable/recyclable alternatives (e.g. Disruptive Packaging; TomKat packaging (see Appendix 2 Literature Review)). This work notes the advantages of polystyrene (PS) eskies: economically viable, robust, light and thermally excellent. However, it is likely that PS eskies will eventually be banned in offshore markets and hence functional alternatives must be identified. This work aligns with wild harvest prawn sustainable packaging research currently being conducted at Curtin University.
- Discussion has commenced with companies able to supply compostable liners/shrink wrap and individual frozen lobster packaging (e.g. Grounded Packaging; Naturplas Packaging). See Appendix 1: Literature Review). This work also aligns with similar finfish and wild harvest prawn sustainable packaging research currently being conducted at Curtin University.
- Plastic components of pots (tags/necks/float savers) have been sent to a New Zealand plastics manufacturing company for assessment of feasibility to construct these components using marine biodegradable alternatives.
- A "better bait" proposal to investigate recyclable/re-useable and compostable materials for bait supply packaging has been developed with a local company.

Table 6: Recommended Case Studies for Phase 2 Project: On-vessel fishing gear

Action category	**Possible Intervention Activity**	**Current status (as basis for Phase 2 project)**	**Considerations**
Reduce / redesign	Plastic-free pot	• Plastic-free alternatives currently exist for pot components (excluding rope and floats). • Many fishers already using wooden pot necks and bait lids. • Lower lifespan and higher economic costs for maintaining plastic-free gear are barriers	• Improve economic viability of plastic-free components less readily used (metal bait baskets) (Bornt et al. in-prep). Upscale manufacturing of plastic-free alternatives (Bornt et al. in-prep). • Incentivizing, and staggering (by component – e.g. necks first) with shift to plastic-free pot (Bornt et al., in-prep).

		to implementation (Bornt et al. in-prep).	• Design may need to be improved for some components to promote functionality and increase lifespan, particularly to suit demands of large-scale fishers (Bornt et al. in-prep).
Reduce	Gear loss reduction interventions	• Most plastic lost to environment is from rope (Bornt et al., 2023). • Interference from other vessels (particularly cargo ships) causes most pot loss (Bornt et al., 2023). • Maintenance / replacement schedules for rope as microplastic release substantially increases after 2 years in operation (Napper et al., 2022).	• Consider strategies for reducing interference from large vessels with lobster pot ropes / floats (Bornt et al. in-prep). • Improve maintenance / replacement schedules to reduce rope breakages and gear loss but could increase rope waste. Offset waste by improving reuse or recyclability of rope (below) (Bornt et al. in-prep).
Redesign	Improved design of rope and floats to increase circularity of plastics	• No suitable plastic-free gear alternatives – so other strategies to reduce plastic for plastic reduction (Bornt et al., in-prep).	• Limited recycling and reuse options for fishing gear in general – particularly, rope and floats. • R&D focused on circularity of design for float and rope. • Directed landfill initiatives – specific bins for rope to delineate waste stream (Bornt et al., in-prep).

Table 7: Recommended Case Studies for Phase 2 Project: Other Plastics.

Action	Possible Intervention Activity	Current status (as basis for Phase 2 project)	Considerations
Rethink/redesign	Production of plastic pot components (bait box; necks; float savers) using marine	Samples have already been sent to a New Zealand company, investigating such novel raw	Time frame Operability

	biodegradable polymers (e.g. PHA).	materials. Wooden or metal construction materials may also be considered (see Bornt et al. 2024).	Cost Design functionality and lifespan / durability Plastic pot waste on beaches impacts SLTO
Rethink/redesign	Consider polystyrene or waxed carton packaging replacements.	Trials have been undertaken on other seafood products (e.g. prawns; whole fish). Internal trials have commenced on recyclable/reuseable/compostable rock lobster cartons for live rock lobster export.	Operability Cost Freight Regulations Market requirements
Reduce	Develop alternate bait supply incorporating recyclable/sustainable crates/cartons and liners.	A proposal from local lobster supply company is currently being finalised to trial an alternate bait product using reuseable bait crates and compostable liners.	Operability Cost Scale
Reduce	Consider necessity of the use of liners or use compostable materials in cartons for frozen whole or tails/heads. Discuss with end-use markets.	Similar trials with compostable liners have been undertaken with other seafood products (e.g. prawns, whole fish and fillets). Some new cartons have been developed that are reported to not require liners.	Operability Market requirements Freight regulations
Reduce	Consider necessity of the use of individual wrapping/liners for frozen whole product and liners for frozen tails/heads or re-place with compostable product. Discuss with end-use markets.		Operability Market requirements Freight regulations
Reduce	Consider necessity of the use of ice packs/gel packs or use re-usable; recyclable; compostable materials. Discuss with end-use markets.		Operability Market requirements Freight regulations
Reduce	Consider necessity of the use of pallet wrap or use	A compostable pallet wrap has been developed. Some companies	Operability Cost.

	compostable pallet protection materials.	no longer shrink wrap wrap pallets.	Freight Regulations Market requirements
Reduce	Consider alternates to single use plastic glove use.	Some reuseable glove strategies have already been implemented in some companies.	Operability Safety
Reduce/recycle	SOP's/education programs for staff focused on plastics reduction.	Some strategies have already been implemented in some companies	Cost Operability
Reduce/recycle	Supply chain communication regarding introduction of alternate packaging materials	Current packaging disposal activities by end-users may not be well understood.	Cost Operability Market Requirements
Reduce	Consider consumables procurement strategies which focus on plastics reduction	Recycling of chemical supply containers already implemented in some companies	Cost

5.2 Outputs

- Developed a comprehensive map of plastics production in terms of volume, form, location within the WRL post-unload supply chain.
- Developed a generic excel datasheet which allows changes to plastics volumes and automatic updating of data for specific context.
- Identified potential interventions with consideration of economics, environmental factors, and legislative implications.
- Provided recommendations for the manufacturing/sourcing, commercial implementation and evaluation of some interventions. Some intervention activity trials have commenced (packaging alternatives, bait supply alternatives; marine biodegradable pot component trials).

5.3 Outcomes

- A report on plastic usage throughout the Western Rock Lobster industry; and
- Recommendations for various Stage 2 activities that could be trialled as potentially feasible plastic alternatives that could be implemented in the WRL industry.

6. Extension

The project involved communication and extension to processors of the WRL industry. The findings and outcomes of this research will continue to be proactively shared with industry stakeholders via the WRL website, newsletters, and social media posts. A results summary PowerPoint with notes has been prepared for use in ongoing extension activities. These activities will be developed in conjunction with the WRL Council.

Publications/Products

Table 6 is a summary of the extension activities of the project.

Table 6: Project Extension Activities and Products

Publication/Product	**Detail**	***Status***
FRDC/WRL/Curtin meetings	*Update meetings*	*Originally fortnightly, now as requested*
Interview BluWave	*Initial walk the chain with processor*	*Completed June 2023.*
Interview Indian Ocean	*Initial walk the chain with processor*	*Completed June 2023.*
Interview Kailis Bros	*Initial walk the chain with processor*	*Completed June 2023.*
Interview Geraldton Fishermen Co-operative	*Initial walk through with processor*	*Completed July 2023.*
FRDC 'New innovations for Seafood industry' WA case studies event	*Project presentation at event*	*Held August 2023*
Meeting with Katrina Bornt on vessel plastics auditors	*Discussion of aligned PhD project on vessel plastic audit and interventions*	*Held in November 2023.*
Meeting with New Zealand (NZ) iindustry and NZ plastics manufacturers (EPL) investigating marine alternatives	*NZ Rock Lobster industry member investigating bait holder alternatives suggests alignment with WRL equipment and project.*	*Meeting held November 2023 with samples to be dispatched to NZ.*
Meeting with sustainable packaging companies	*"Fit for purpose" discussions leading to planned trials:*	*The collaboration is ongoing.*
Kailis Bros Briefing	*Discussion of results*	*March 2024*
Indian Ocean Lobster Briefing	*Discussion of results*	*April 2024*
WRL meeting	*Discussion of results and draft final report.*	*May 2024*

7. References

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Appendix 1: Ethics Documents

CONSENT FORM

HREC Project Number:	**HRE2023-0280**
Project Title:	FRDC 2020/062: **Minimising plastic in the western rock lobster industry (Phase 1 – scope and identify),**
Chief Investigator:	Assoc Prof Janet Howieson
Other Researcher:	TBA
Version Number:	1
Version Date:	22 May 2023

I have read the information statement version listed above and I understand its contents.
I believe I understand the purpose, extent, and possible risks of my involvement in this project.
I voluntarily consent to take part in this research project.
I voluntarily consent to the interview being audio/video recorded.
I have had an opportunity to ask questions and I am satisfied with the answers I have received.
I understand that this project has been approved by Curtin University Human Research Ethics Committee and will be carried out in line with the National Statement on Ethical Conduct in Human Research (2007).
I understand I will receive a copy of this Information Statement and Consent Form.

Participant Name	
Participant Signature	
Date	

Declaration by researcher: I have supplied an Information Letter and Consent Form to the participant who has signed above.

Researcher Name	
Researcher Signature	
Date	

Note: All parties signing the Consent Form must date their own signature.

Information Sheet

PARTICIPANT INFORMATION STATEMENT

HREC Project Number:	**HRE2023-0280**
Project Title:	**Minimising plastic in the western rock lobster industry (Phase 1 – scope and identify),**
Chief Investigator:	Assoc Prof Janet Howieson
Other Researchers:	TBA
Version Number:	1
Version Date:	23 May 2023

What is the Project About?

Background:

The Australian Western Rock Lobster industry is auditing plastic use. The audit will be both on vessel and through the processing facility. Once the audit is completed, possible interventions to replace plastics will be proposed and economic and technical/operational feasibility assessed.

Industry consultation is requested to gather information for the study.

Project Significance:

To the best of our knowledge, this plastics audit is a novel approach for the Australian seafood industry.

Project Objectives:

- Identify where and why plastic is used in the WRL industry.
- Identify viable environmentally friendly plastic alternatives

Who is Doing the Research?

This project is being conducted by Assoc Prof Janet Howieson (Food Science, Curtin University).

This research project is funded by a grant from the WRL IPA of the Fisheries Research and Development Association

There will be no costs to you and you will not be paid for participating in this project.

Why am I being asked to take part and what will I have to do?

You have been asked to take part in this research because you work in the WRL industry.

You will participate in a semi-structured interview for approximately 45 minutes where you will be asked a set of questions aimed at stimulating discussion about the plastics use in the WRL supply chain.

The interview will take place at a mutually convenient location.

- We will ask you questions about your operations and industry practices. We are primarily interested in understanding what kind of plastic is used, where it is recycled/re-used or disposed, any ideas you have to reduce plastic use and barriers and opportunities for interventions.
- The interview may be recorded so that we can concentrate on the conversation, rather than on taking notes. We may make a full written transcript of the recording after the interview which will be sent to you.
- In the weeks following the interview, you may also be asked for your feedback on the supply chain maps that are created.

Are there any benefits to being in the research project?

- You may not benefit directly from participating in this research. However, people sometimes appreciate the opportunity to discuss their opinions and insights.
- Your participation will be greatly appreciated and valued as it will contribute to understanding plastics use and possible interventions in the WA Rock Lobster industry.

Are there any risks, discomforts, or inconveniences from being in the research project?

- There are no foreseeable risks from this research project.
- We will adhere to all state government COVID-19 guidelines and restrictions (e.g. travel restrictions, social distancing measures, contact tracing) to mitigate any potential risks related to the pandemic.
- Apart from giving up your time, we do not expect that there will be any risks or inconveniences associated with taking part in this study.

Who will have access to my information?

- The information collected in this research will be re-identifiable (coded). This means that we will collect data that can identify you but will remove identifying information on any data and replace it with a code (e.g. Firm A, B, C) when we analyse the data.
- Only the research team have access to the code to match you or your company if it is necessary to do so.
- Any information we collect will be treated as confidential and used only in this project unless otherwise specified.
- The following people will have access to the information we collect in this research: the research team, WRLC; FRDC and, in the event of an audit or investigation, staff from the Curtin University Office of Research and Development.
- Electronic data will be password-protected and hard copy data (including video or audio tapes) will be in locked storage.
- The information we collect in this study will be kept under secure conditions at Curtin University for 7 years after the research is published and then it will be destroyed.
- The results of this research may be presented at conferences or published in professional journals. You will not be identified in any results that are published or presented.

Will you tell me the results of the research?

- A summary of the project’s overall results will be sent to participants.
- If you are interested in obtaining a summary of the results, please contact the researchers after November 2023.
- We intend to publish the results in journal articles (and in reports to our industry partners and funders (WRLC and FRDC).

Do I have to take part in the research project?

Taking part in a research project is voluntary. It is your choice to take part or not. You do not have to agree if you do not want to. If you decide to take part and then change your mind, that is okay, you can withdraw from the project.

If you choose to leave the study, we will use any information collected with your permission.

What happens next and who can I contact about the research?

The lead contact for this research is Assoc Prof Janet Howieson of Curtin University. Janet can be reached via the following details:

a. (08) 9266 2034/0423840957
b. J.howieson@curtin.edu.au/

If you decide to take part in this research we will ask you to sign the consent form. By signing it is telling us that you understand what you have read and what has been discussed. Signing the consent indicates that you agree to be in the research. Please take your time and ask any questions you have before you decide what to do. You will be given a copy of this information and the consent form to keep.

Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number 2023-0281). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

Interview Guide

Minimising plastic in the western rock lobster industry (Phase 1 – scope and identify),

Assoc Prof Janet Howieson, Curtin University and research assistants

Opening Script

Hi [participant name]. Thank you for taking the time to talk to me about plastic use in the Western Rock Lobster industry. I'm Janet Howieson or …... We would like to speak with you today, for about 40 minutes or so, about mapping plastic use and finding new intervention opportunities to reduce plastic waste in the WRL industry.

There are just a few house-keeping points to cover before we start our conversation *[stated verbally]*:

This discussion may be recorded to ensure the accuracy of the data collected.
Your contribution will be anonymised when we analyse the data and write up the final results.
You are free to withdraw from the discussion at any time without prejudice.
And finally, it would be very much appreciated if you could please complete and return the consent form to me before we get started.

To start things off, could you describe your business and the WRL supply chain?

Facilitator prompts:

Approximate Quantities processed and outputs/outcome/product formats.
Developing a Processing flow chart.
Plastics use in the flow.

At what points in your process are plastics used?

Facilitator prompts:

Soft and hard plastics
Any recycling
Waste streams
Waste end points
Ideas for interventions

Finally, what are your thoughts about the barriers and opportunities in replacing plastics with other alternatives?

Facilitator prompts:

Financial – costs, dollar value/economic feasibility
Operational/Technical
Supply chain factors

Before we finish, are there any issues that we haven't touched on? Would you like to add any more thoughts?

Are there any others in the supply chain you think would be good for me to contact? If I have any other questions, would you mind if I gave you a call or quick e-mail?

Thank you so much for taking the time to speak to us today. Your contribution has been really valuable for my research project.

We'll be reporting back to WRLC in a few months, would you like to receive a copy of the report?

If you have any further comments or have any questions about the research, please feel free to get in touch. Our contact details are on the Participant Information sheet that you received.

Appendix 2 Literature Review

1. Plastic use and packaging and shift towards sustainability

Global plastic production has increased exponentially – In 1950's the world produced just two million tonnes. It now produces over 450 million tonnes due to its durability, versatility and low cost (Geyer et al., 2017). However, mismanagement of plastic leads to environmental pollution especially in oceans and rivers. Recent studies suggest that between 1 and 2 million tonnes of plastic (around 0.5%) enter the oceans annually (OECD, 2022). Approximately 170 trillion plastic particles are currently present in the ocean (Eriksen et al., 2023), with an additional thirty times that amount believed to have gathered in seafloor sediment (Barrett et al., 2020). Macroplastics resulting from fishing activities pose threats to marine life and seabirds, establishing a significant presence as the predominant human debris on coral reefs (Pinheiro et al., 2023). Notably 80% of global ocean plastics come from land-based sources emphasising the need for sustainable alternatives (Li et al., 2016). Plastics also contribute to global emissions, accounting for about 3.3% of total emissions (Ritchie et al., 2023).

The chart below (Figure 1) depicts plastic emissions and their respective origins within the supply chain. Approximately 90% of the emissions stem from the production stage, which involves the conversion of fossil fuels into plastic materials. Conversely, emissions associated with the end-of-life phase typically constitute a minor portion.

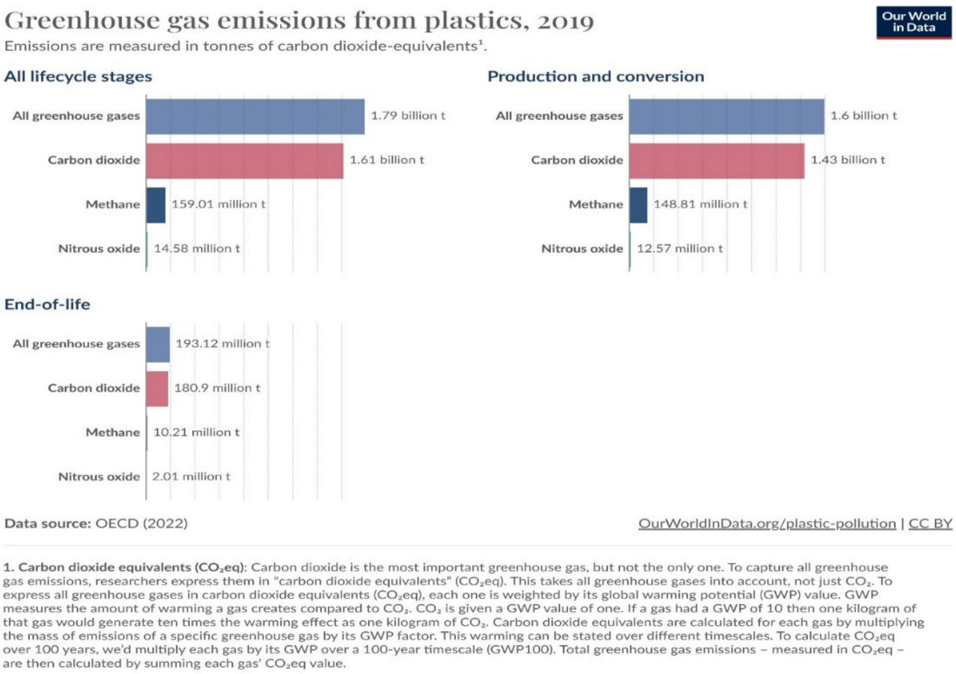

Figure 1. Plastic Emissions by Supply Chain Stage. Data Source: OECD, 2022. Retrieved from https://ourworldindata.org/

The seafood sector is actively engaged in sustainability efforts, as evidenced by the Seafood Industry Australia 'Our Pledge' to reduce their reliance on plastic, recycle plastics where possible and explore alternatives to plastic products. The challenges faced by the Seafood industry include the recognition that packaging is the largest contributor to plastic waste and is the dominant form of waste because it is the sector that uses the most plastic and has a very low product lifetime (OECD, 2022).

The growing concern about the environmental impact of plastic waste has led industries, including fisheries, to reassess their practices. Plastic waste estimates suggest 20-30% of ocean plastics come from marine sources (fishing nets, ropes, lines and abandoned vessels) and 70-80% from land (via coastlines and rivers). The Great Pacific Garbage Patch (GPGP) reports more than half of plastic pollution comes from marine sources due to intense fishing activity in the Pacific Ocean (Lebreton et al., 2018) with the most recent estimates confirming that abandoned, lost or otherwise discarded fishing gear make up 75% to 86% of floating plastic mass (greater than 5 cm) (Lebreton et al., 2022). Furthermore, data from 2015 reveals compelling evidence of GPGP's rapid accumulation of plastic as depicted in the chart below (Figure 2). This chart illustrates the sources of plastic to the GPGB, categorised by plastic use and particle size. The significant contribution of marine sources underscores the urgent need for comprehensive strategies to mitigate plastic pollution in our oceans.

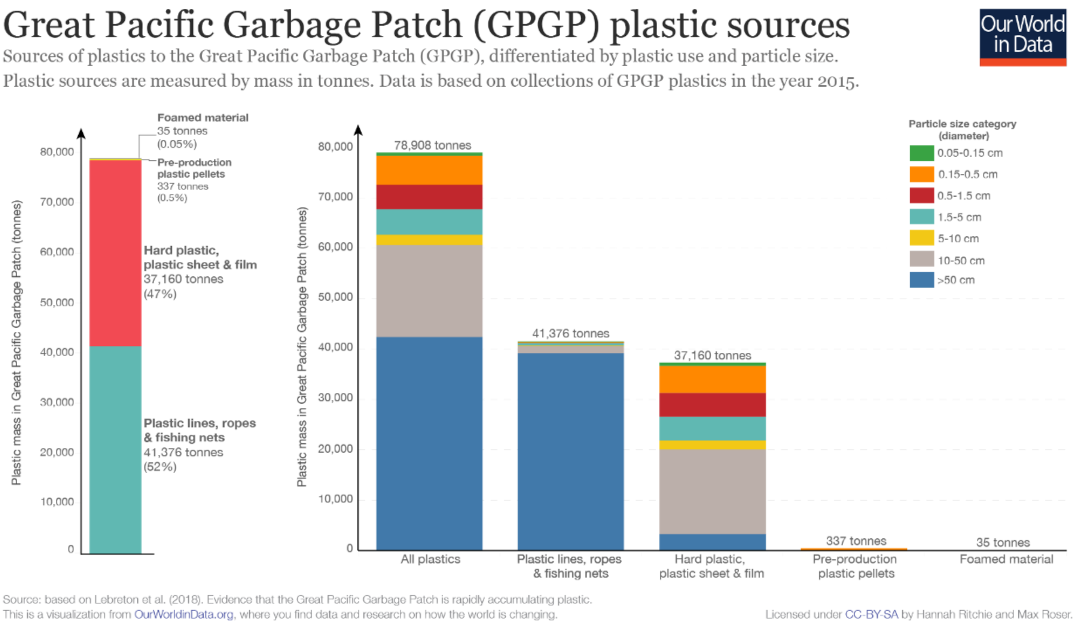

Figure 2. Sources of plastic to the Great Pacific Garbage Patch in the year 2015. Data Source: Lebreton et al. (2018). Retrieved from https://ourworldindata.org/

The Western Rock Lobster (WRL) industry is undertaking a comprehensive study to address plastic usage and transition towards more sustainable alternatives. This review is part of the first stage of that study FRDC 2020-062: Minimising plastics in the WRL industry: Phase 1 scope and identify.

2. General Definitions: Reuse, Recycle, Biodegradable, Compostable Packaging

Plastic waste management strategies are integral to the research study and is informed by a comprehensive waste reduction framework depicted in Figure 3 below. The framework classifies waste management strategies into various categories, including avoidance, reuse, recycling, energy recovery, and disposal (Commonwealth of Australia, 2017)

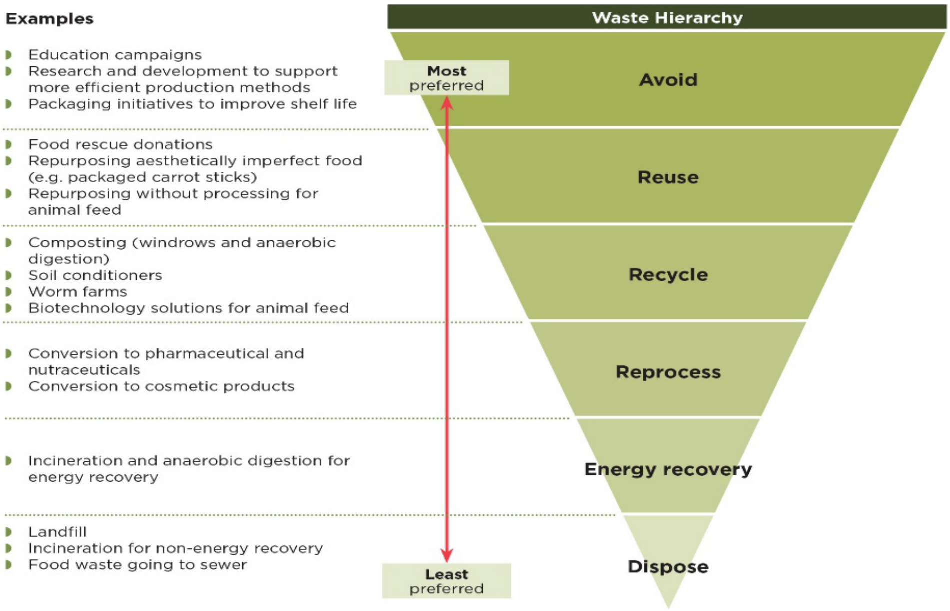

Figure. 3 Waste reduction framework (source: National Food Waste Strategy 2017).

Furthermore, the Australian Packaging Covenant Organisation (APCO) has released guidelines aimed at improving packaging sustainability within the Australian food service industry (APCO, 2020). The resource was developed in collaboration with various stakeholders including government entities, the food service industry, waste handlers, composters, recyclers, academics and community groups. This collaborative effort underscores the importance of adopting a holistic approach to waste management as in Figure 4, in line with the principles outlined in existing waste reduction frameworks.

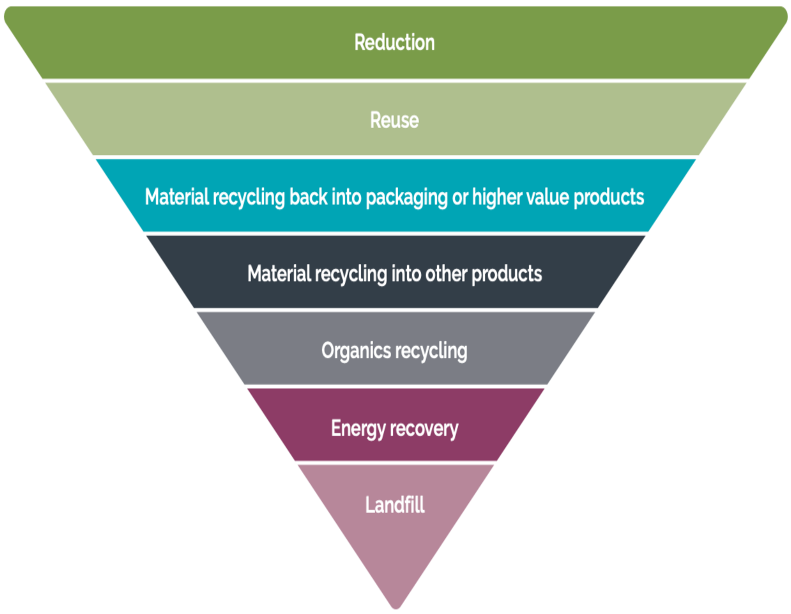

Figure 4. APCO guidelines for improving packaging sustainability for the Australian Food service industry, 2019

Moreover, as emphasized by the World Economic Forum, in a properly built circular economy, the primary focus should be on waste prevention rather than solely relying on recycling. The Forum asserts that preventing waste from being created in the first place is the most realistic and effective strategy, highlighting the importance of prioritising avoidance strategies within waste management principles (World Economic Forum, 2019).

Critical to this understanding of plastic reduction strategies are some key definitions:

- Reusable Packaging: A characteristic of packaging that has been conceived and designed to accomplish within its life cycle a certain number of trips or uses for the same purpose for which it was conceived (Ellen Macarthur Foundation, 2019).
- Material Recycling: Refers to reprocessing, by means of a manufacturing process, of a used packaging material into a product, a component incorporated into a product, or a secondary (recycled) raw material; excluding energy recovery and the use of the product as a fuel (APCO, 2021a).
- Compostable packaging: A packaging or packaging component (1) is compostable if it is certified to AS4736, AS5810 or a similar compostability standard, and if it is successful post-consumer (2) collection, (sorting), and composting is proven to work in practice and at scale (3).
- Biodegradable plastic/ packaging: A generic term that indicates a plastic is biologically available for microbial decomposition, with no detail on its breakdown outputs, time or extent of degradation or end environments (APCO, 2021b).

Notes:

1. *ISO 18601:2013: A packaging component is a part of packaging that can be separated by hand or by using simple physical means (e.g. a cap, a lid and non in-mould labels).*
2. *ISO 14021 clarifies post-consumer material as material generated by households or by commercial, industrial and institutional facilities in their role as end users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain.*
3. *'At scale' implies that there are significant and relevant geographical areas, as measured by population size, where the packaging is actually composted in practice (Ellen Macarthur Foundation, 2019).*

3 Plastic Categorisation and Recyclability Status

The plastic identification code is a series of symbols that assist product designers, manufacturing and recycling industries, government agencies and consumers to identify the types of polymers used in the manufacture of the product or packaging. The symbols are normally embossed on the bottom of the plastic containers and bottles, or at the back of packages. The voluntary plastic code ('the code') was created by the Plastics and Chemicals Industry Association (PACIA) in 1990. The coding system consists of seven symbols (Table 1).

Table 1. Plastic Identification Code: A guide to polymer identification symbols and their significance (source: PACIA, 2005).

Plastics Identification Code

The Plastics Identification Code identifies the type of plastic resin a product is made from. The Code makes it easier for re-processors to identify and separate used plastics for a range of new applications. Consistent with the waste hierarchy, single and mixed materials can be recycled into a range of new products or converted into energy.

TYPE OF PLASTIC		PROPERTIES Incl. Specific Gravity & Heat Distortion Temp.	APPLICATIONS: Virgin Grades	APPLICATIONS: Recycled grades MAJOR USE / minor use
1 PET	Polyethylene Terephthalate **PET**	Clear, tough, solvent resistant. Used for rigids, sheets and fibres. Softens: 55° C SG = 1.38	Carbonated soft drink bottles, fruit juice bottles, pillow and sleeping bag filling, textile fibres	**BEVERAGE BOTTLES** Clothing, geo-textiles, bottles for detergents etc., laminated sheets, clear packaging film, carpet fibres
2 HDPE	High Density Polyethylene **HDPE**	Hard to semi-flexible, waxy surface, opaque. Softens: 60° C SG = 0.96	Crinkly shopping bags, freezer bags, milk bottles, bleach bottles, buckets, rigid agricultural pipe, milk crates	**FILM, BLOW MOULDED CONTAINERS** Agricultural pipes, pallets, bins for compost and kerbside collections, extruded sheet, moulded products, crates, garden edging, household bags, oil containers, pallets.
3 V	Unplasticised Polyvinyl Chloride **UPVC**	Hard rigid, can be clear, can be solvent welded Softens: 70° C SG = 1.40	Electrical conduit, plumbing pipes and fittings, blister packs, clear cordial and fruit juice bottles	**PIPE, FLOORING** Pipe and hose fittings, garden hose, electrical conduit, shoes, road cone bases, drainage pipes, electrical conduit and ducting, detergent bottles
	Plasticised Polyvinyl Chloride **PPVC**	Flexible, clear, elastic, can be solvent welded Softens: 70° C SG = 1.35	Garden hose, shoe soles, cable sheathing, blood bags and tubing, watch straps, rain wear	
4 LDPE	Low Density Polyethylene **LDPE** Linear: **LLDPE**	Soft, flexible, waxy surface translucent, withstands solvents Softens: 40° C SG = 0.92	Garbage bags, squeeze bottles, black irrigation tube, stretch and shrink films, silage and mulch films, garbage bins	**FILMS: BUILDERS, CONCRETE LINING and BAGS** Agricultural pipe, nursery & other films
5 PP	Polypropylene **PP**	Semi-crystalline, wide property and application range. Translucent (can be transparent), hard, flexible, good chemical resistance, low SG. Softens: 80° C SG = 0.90	Film, carpet fibre, appliance parts, crates, automotive applications, toys, pails, housewares / kitchenwares, bottles, caps and closures, furniture, plant pots.	**CRATES, BOXES, PLANT POTS** Compost bins, garden edging, irrigation fittings, building panels
6 PS	Polystyrene **PS**	Clear, glassy, rigid, brittle, opaque semi-tough, melts at 95°C. Affected by fats and solvents. Softens: 85° C PS = 1.06	Refrigerator bins & crispers, air conditioner, office accessories, coat hangers, medical disposables. Meat & poultry trays, yoghurt & dairy containers, vending cups	**INDUSTRIAL PACKAGING, COAT HANGERS, CONCRETE REINFORCING CHAIRS** Moulded products, coat hangers, office accessories, spools, rulers, video cases and printer cartridges
	Expanded Polystyrene **EPS**	Foamed, light weight, energy absorbing, heat insulating Softens: 85° C SG = 0. 92	Drinking cups, meat trays, clamshells, panel insulation, produce boxes, protective packaging for fragile items	**PRODUCE BOXES** Waffle pods for buildings, building and picture frame mouldings
7 OTHER	**OTHER** : Includes all other resins and multi materials (eg laminates). Eg acrylonitrile butadiene styrene (ABS), acrylic, nylon, polyurethane (PU), polycarbonates (PC) and phenolics.		Automotive, aircraft and boating, furniture, electrical and medical	**AGRICULTURAL PIPING** Furniture fittings, wheels and castors. Fence posts, pallets, outdoor furniture and marine structures

HDPE, LDPE, PS, EPS and nylon make up for the majority of packaging and are the key plastics used by the Australian seafood Industry with the potential to pollute the ocean. Several plastics fall into the category of non-degradable, signifying their inability to decompose but rather undergo fragmentation into increasingly smaller particles. Photodegradation, resulting from UV radiation, is one mechanism through which materials can gradually break down. Table 2 highlights the recyclability status of each plastic type in Australia, providing insight into their environmental impact and potential for sustainable management.

Table 2. Type of plastics and their recyclability.

Type	Description	Recyclability in Australia
Polyethylene terephthalate (PET or PETE)*	Clear, strong, and lightweight plastic commonly used in beverage bottles, food containers, and synthetic fibers (such as polyester). Widely used in packaging due to its desirable properties	Packaging captured in container deposit schemes, existing recycling PET facilities. Good polymer for mechanical recycling pathways. An ideal polymer for depolymerisation
High-density polyethylene (HDPE)*	Versatile plastic known for its high strength-to-density ratio, making it suitable for a wide range of applications including bottles for milk and detergent, plastic bags, pipes, and toys.	Municipal waste collection via MRF facilitates. Considered a good polymer for mechanical recycling pathways. When mechanical is not possible, best suited for conversion technologies.
Polyvinyl chloride (PVC)*	Durable and versatile plastic used in construction, healthcare, packaging, and other industries. It can be rigid or flexible depending on additives and processing methods. PVC is known for its resistance to weathering, chemicals, and abrasion.	Collection scheme for some medical plastics. Considered contamination in municipal plastics collections. Opportunities for greater collection in building and construction sector. Undesirable for conversion technologies. Best suited for purification technologies.
Low-density polyethylene (LDPE)*	Flexible and lightweight plastic used in packaging films, bags, squeeze bottles, and coatings. It is resistant to moisture and chemicals but has lower tensile strength compared to HDPE	Consumer packaging wrap collected by REDcycle in Australian supermarkets. Clean post-industrial film suitable for mechanical recycling. Also suitable for conversion technologies
Polypropylene (PP)*	Tough and heat-resistant plastic used in a variety of applications including packaging, automotive components, textiles, and medical devices.	Low recycling rate in Australia. Suitable for either conversion or purification technologies.
Polystyrene (PS) and Expanded polystyrene (EPS)*	Versatile plastic known for its clarity and rigidity. It is used in food packaging, disposable cups, and foam insulation. EPS is a lightweight, rigid foam derived from PS, commonly used in packaging, insulation, and construction materials.	Growing focus to reduce PS in packaging to meet recovery targets. EPS packaging collected at transfer stations. There is some recycling into the built environment. The majority of what is collected is currently exported. Excellent candidate for purification technologies. Also good for conversion and depolymerisation technologies.
Polyhydroxyalkanoates (PHA)#	Biodegradable polymers synthesized by microorganisms from renewable carbon sources.	Requires competent recycling route. Presently, it is not clear which recycling methods will have the major impact in the management of polyhydroxyalkanoate waste
Polylactic acid (PLA)##	Biodegradable polymer derived from renewable biomass sources such as corn, cassava, sugarcane, or sugar beet pulp.	PLA is biodegradable in controlled composting environments within three months which currently means a large composting facility that reaches 140 degrees Fahrenheit for ten consecutive days. Recycling companies regard PLA as a contaminant that must be sorted out and disposed of separately.

Data sourced from: *King, S., Hutchinson, S. A., & Boxall, N. J. (2021). *Advanced recycling technologies to address Australia's plastic waste*. CSIRO, Australia. #Vu, D. H., Åkesson, D., Taherzadeh, M. J., & Ferreira, J. A. (2020). Recycling strategies for polyhydroxyalkanoate-based waste materials: An overview. *Bioresource Technology, 298*, 122393. ##Morath, S. J. (2022). Plastic Alternatives: Bioplastics and Material Replacement. In *Our Plastic Problem and How to Solve It* (pp. 161-170). Cambridge University Press.

The commercial fishing Industry, both land- based and sea-based, plays a crucial role in providing seafood to meet global demand. However, the use of plastics in various aspects of commercial fishing has raised significant environmental concerns, particularly regarding their impact on marine systems.

The land-based aspects of commercial fishing, encompassing the processing, packaging, and distribution of fresh seafood, heavily involve the use of plastics. These plastics are utilised for packaging materials, storage containers, and transportation vessels contributing to the potential leakage of plastics into the environment, including marine ecosystems.

In sea-based commercial fishing, plastics also play a vital role, albeit in different contexts. Plastic materials are widely used in equipment such as nets, lines, ropes, and buoys, essential for catching fish and shellfish. Similar to land-based processes, the disposal of these plastics poses environmental challenges, especially considering the harsh conditions at sea, where proper waste management becomes even more difficult.

The chart (Figure 4) provided illustrates the estimated decomposition times for various plastics and commonly found marine debris items. For instance, the fishing lines (sea-based plastic) have an estimated breakdown time of 600 years, while plastic bottles (land-based plastic) take approximately 450 years to degrade. These staggering decomposition times highlight the long-lasting environmental impact of plastic pollution on marine ecosystems.

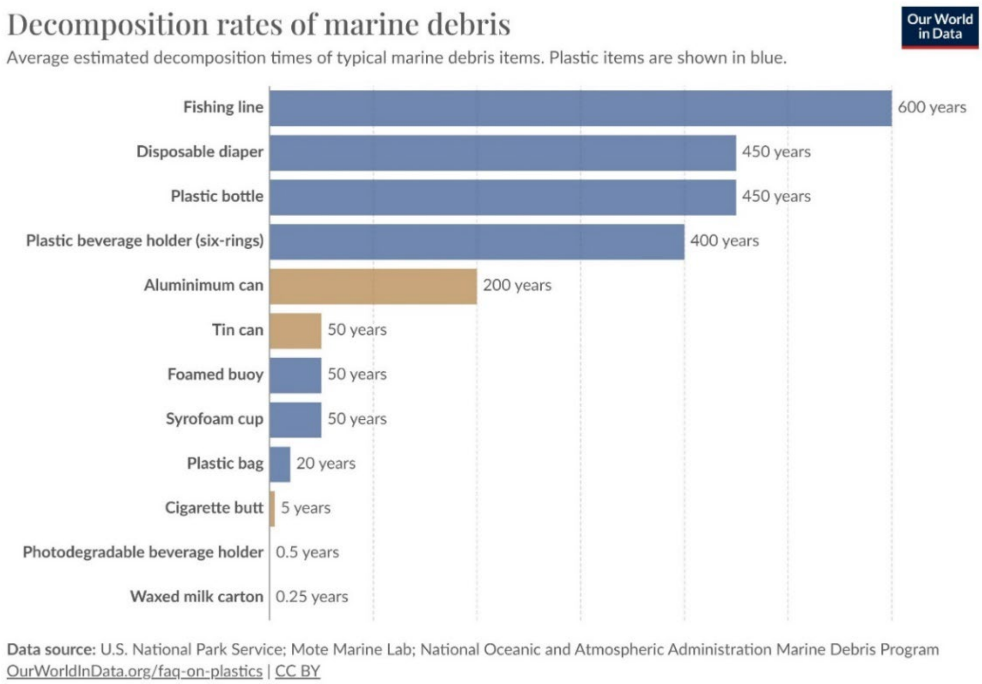

Figure 4. Estimated Decomposition Rates of Common Marine Debris Items (data source: Decomposition times of marine debris - U.S National Park Service – processed by Our World in Data).

4 Current Status of 2025 National Packaging Targets in Australia

In 2018, Australia set ambitious 2025 National Packaging Targets, supported by both industry and government collaboration. Overseen by the Australian Packaging Covenant Organisation (APCO), these targets aim for comprehensive sustainability in packaging by December 31, 2025. The objectives include making 100% of packaging reusable, recyclable, or compostable, achieving a 70% recycling or composting rate for plastic packaging, and incorporating 50% recycled content in packaging. Additionally, the targets seek to phase out problematic single-use plastics. However, recent data indicates challenges in meeting these targets by the deadline. APCO collects annual benchmark data, revealing obstacles to full achievement. According to the latest report Australia recycles just 18% of plastic packaging and will only get two-thirds of its way to its national target of 70% by 2025. The responsibility for these targets rests collectively on brand owners, industry, government, community groups, and academia. APCO utilises the Collective Impact Framework to facilitate change, emphasising the ongoing need for collaboration. As Australia addresses waste and recycling challenges, the focus remains on practical and unified efforts to reach the critical 2025 packaging targets.

5. Mapping Plastic/Packaging Use in Seafood Industry Supply Chains

The evolution of fishing gear materials reflects a historical shift: early gear predominantly used natural fibers such as cotton, hemp, or flax. However, post-World War II, the fishing industry transitioned to synthetic materials, particularly polyethylene and polypropylene nets, and nylon monofilament lines known for buoyancy and sinking properties, respectively. Fishing equipment made from these synthetics now offers cost-effectiveness, durability, lightweight properties, robustness, and enhanced efficiency compared to traditional gear.

Earlier efforts to investigate plastic usage in the seafood industry involved a desktop review in 2005 through FRDC project 2004-410, conducted by OceanWatch Australia. Despite elevated plastic utilisation in the commercial wild catch sector, the study identified plastic and waste minimisation initiatives already in place among fishers and cooperatives. The primary challenge highlighted was the proper disposal of plastic waste, especially post-harvest, involving seafood wholesalers, retailers, and consumers. The study also pinpointed opportunities for plastic alternatives within the seafood industry (OceanWatch Australia, 2007). Table 3 provides a summary of various plastic products used in the seafood supply chain, compiled from surveys, interviews, and workplace observation (OceanWatch Australia, 2007). The table categorises each item based on its recyclability, potential scrap value, available alternatives, and the feasibility of replacement with environmentally friendly options. It outlines typical plastic items used in the seafood sector supply chain and suggests possible alternatives, including recycling options, reuse possibilities, and environmentally friendly substitutes. The information aims to guide the industry towards more sustainable practices in plastic usage.

Table 3: Typical Plastic items used in the seafood sector supply chain and possible alternatives

Plastic item	Recyclable	Possible scrap value	Alternatives	Possible alternatives available
Polyethylene and polypropylene	✓	✓		Recycling options only
Monofilament lines	✓	✓		Recycling options only
Ropes	✓	✓		Recycling options only
Buckets (consumable containers)	✓	✓		Recycling options only
Floats (foam)	✓	✓		Recycling options only
Floats (plastic)	✓	✓		Recycling options only
Fish boxes (hard plastic)	✓	✓		Recycling options only
Tuna bags		✓	✓	Recycling or re-use options
Tuna mats	✓			Recycling or re-use options
EPS boxes	✓	✓	✓	Coolseal-type boxes
Produce bags including bait bags	✓	✓		Starch-based biodegradable bags
Sheeting	✓	✓		Starch-based biodegradable bags
Carry bags	✓	✓	√	Starch-based biodegradable bags

				Calico bags. Paper bags. Non-woven bags.

In the examination of plastic and packaging usage within seafood industry supply chains, a study conducted in 2021 focused on the West Coast Rock Lobster Managed Fishery. This investigation, centered on a major Australian pot fishery, sought to quantify plastic gear loss through interviews with 50 commercial fishers. The study revealed an estimated annual percentage of plastic gear loss at 10.8%, alongside an "active" gear loss rate of 0.2% per fishing effort. Notably, these figures were observed to be below global estimates for analogous pot fisheries, indicating a relatively low plastic gear loss in this specific fishery. The primary contributors to plastic gear loss were identified, with rope constituting 47.0%, pot components at 30.7%, and floats at 22.3%. Predominantly, 78.0% of these components were composed of polypropylene and polyethylene. This breakdown underscores specific areas within the supply chain that warrant consideration in efforts to address plastic pollution. The findings contribute empirical data to the understanding of plastic usage in seafood industry supply chains, emphasizing the need for nuanced considerations regarding gear composition and the implementation of preventative measures to mitigate plastic contamination at the source (Bornt et al., 2023).

The work by Loubet et al. (2022) proposed a methodology for quantifying flows of plastics from the life cycle of seafood products to the environment. This methodology addressed a gap in current Life Cycle Assessment (LCA) frameworks, which often do not adequately consider plastic losses and related impacts. Building on the suggestions from the Plastic Leak Project, this framework aimed to quantify loss rates and final release rates for various types of micro- and macro-plastic losses occurring at different life cycle stages of seafood products, such as abandoned, lost, and discarded fishing gear (ALDFG), marine coatings, polymer pellets, tire abrasion, and mismanaged plastic at the end of life. Through a case study focused on French fish products, the research successfully validated the proposed methodology, demonstrating its applicability. The study revealed plastic losses ranging from 74 mg to 4350 mg per kg of consumed fish (Loubet et al., 2022).

Concurrently a separate study in Norway conducted a system-wide analysis of typical fishing gears used for commercial fishing. The study, based on a Material Flow Analysis (MFA), revealed that commercial fishing in Norway contributes around 380 tons per year of plastic from lost fishing gears and parts, with gillnets, longlines, and traps identified as main contributors (Deshpande et al., 2020).

A 2023 Peruvian study aimed to identify and quantify the major flows of plastic waste accumulating in the ocean from ocean-based sources within the Peruvian Economic Exclusive Zone (EEZ). Through a comprehensive material flow analysis, the study analysed the stock of plastic and its release to the ocean by various Peruvian fleets, including the fishing industry, merchant vessels, cruises, and boating vessels. The findings estimate 2715 to 5584 metric tons of plastic waste in 2018, with the fishing fleet representing 97% of emissions. Fishing gear loss is a major contributor (Deville et al., 2023).

In alignment with this concern for the long-term sustainability of marine environments and fishing industries, the study "Quantification of Plastics in Agriculture and Fisheries at a Regional Scale: A Case Study of South West England" conducted by Correa-Cano et al. (2023) provides valuable insights into the regional-scale plastic waste generation from both agriculture and fisheries activities. Focusing on the South West England region, this study evaluates the plastic waste generated by land-based agricultural practices and the fishing sector using a mass balance approach. They found a significant amount of plastic waste generation in both sectors, with 49 kt of plastic waste generated in agriculture alone, 47% of which has an unknown fate. Additionally, the study estimates 454 t/year of fishing gear waste, further highlighting the scale of plastic pollution originating from these industries.

Adding to the global context, a 2022 study in of New Zealand's commercial fin fishing industry sought ways to prevent marine plastic pollution leakage. Conducted through a case study approach focused on Moana New Zealand, the largest Māori-owned seafood company. The findings reveal extensive plastic usage in both land and sea-based operations, with expanded polystyrene bins identified as a key concern. Cost is identified as a significant barrier to reducing plastic usage, requiring operational changes in fish processing and distribution. Despite this, there is a general willingness among participants to improve plastic use for the long-term sustainability of the marine environment and the fishing industry (Croft & Farrelly, 2021). The study provided a comprehensive list of mechanisms to reduce plastic usage throughout the fin fish supply chain as presented in Table 4 below.

Table 4 Mechanisms to reduce plastic usage throughout the fin fish supply chain (Moana New Zealand).

Action	Strategy	Actor/s
Rethink	Rethink global distribution system - scope for circularity and container return scheme (poly bin)	Industry/Management
	Collaborate with other members of the industry for the procurement of wool cool as a poly bin alternative - economies of scale	Industry/Management
	Consider the ways that Extended Producer Responsibility would work within this supply chain	Management
Redesign	Continue development of kelp poly bin prototype	Management
	Redesign plastic packaging to ensure it is fully recyclable in onshore recycling facilities (or that it is compostable)	
	Work towards finding a redesigned fishing net that uses an alternative to plastic	Management/Fishers
	Conduct research about viable plastic alternatives to fishing gear such as ropes	Fishers/Management
Reduce	Set specific plastic reduction targets throughout entire operations	Management
	Evaluate current procurement practices and switch to suppliers with better management or to products containing more less virgin plastic	Management
	Prohibit the purchase of non-recyclable or SUP products from producers (i.e plastic wrapped bait)	Management
	Phase out single use and hard to recycle plastics throughout all operations	Management
	Implement a reduction in ice and bait bags and food packaging on fishing vessels	Fishers/ Management
Reuse	Ensure fishing gear is re-used and repaired as much as possible	
Recycle	Ensure all plastic used in packaging and processing is recyclable in domestic recycling facilities	Management
	Provide adequate information and education about recycling to all staff	Management
	Support initiatives to recycle products such as gum boots (which can be made into the mats on childrens play equipment)	Management
	Collaborate with local companies who are using recycled fishing nets or collected MPP to produce certain products	Management
	Ensure mandatory recycling of fishing gear such as nets	Management
	Collaborate with Terra Cycle to establish methods to reduce plastic waste in factory	Management
Recover	Ensure lost fishing gear is reported and retrieved where possible	Fishers
	Ensure mandatory reporting of lost gear	Management
	Develop gear audit system of plastics on and off vessel	Management
	Incentivise the collection of MPP of fishers while at sea	Management
	Organise community beach cleans in areas of high fishing activity	Management
	Continue developing collaborative project with ghost diving NZ	Management
	Ensure mandatory marking of fishing gear	Management

Data source: Croft, F., & Farrelly, T. (2021). Tackling plastic pollution in New Zealand's fin fishing industry: Case study of Moana New Zealand.

Despite the valuable insights provided by studies such as these, accurately quantifying the generation and distribution of plastic waste across the supply chain remains a challenge. While there is extensive literature on marine litter surveys, including studies on floating debris (Matsumura & Nasu, 1997; Eriksen, 2014) and beach surveys (OSPAR Commission, 2018), quantification of plastic waste generation in the seafood sector is scarce.

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6. Sustainable Seafood Supply Chains: Current status of Plastics/Packaging used and Suggestions for Sustainable alternatives

The existing plastics management framework in Australia predominantly emphasises 'plastics-back-to-plastics.' However, applying this framework across regional and remote areas, where infrastructure, such as Material Recovery Facilities and Advanced Recycling Facilities, is economically unviable, poses significant challenges (Ocean Watch Australia. (2007). It is similarly suggested that complex designs, including material types and blends, coupled with contamination from biological materials, further complicate the recycling of most fishing and aquaculture equipment. The operational remoteness and inadequate infrastructure in ports exacerbate the challenge, restricting the current circularity potential of the industry (Ocean Watch Australia, 2007). Hence, it is acknowledged that there is a need to expand attention and allocate resources to explore environmentally friendly alternatives to traditional plastics. Furthermore, the importance of single-use packaging, despite its short lifespan, cannot be understated as it serves a critical function by preserving the freshness of seafood products. This aspect adds another layer of complexity to the plastic usage challenge.

This section discusses current initiatives and innovations to prevent plastics from entering marine food chain and to drive efforts to reduce, reuse, recycle.

6.1 Global Initiatives

The SeaBOS initiative

Seafood Business for Ocean Stewardship (SeaBOS) is a collaboration between nine of the world's largest seafood companies to help other companies lead a global transformation towards sustainable seafood production and a healthy ocean. The member companies represent over 19% of the world's seafood production and operate over 465 subsidiaries. SeaBOS developed the "City to Sea" Framework, a comprehensive strategy targeting areas where the seafood industry can significantly reduce plastic pollution. It involves initiatives such as biennial reporting plastics footprints, adoption of alternative materials, reduction, reuse, and recycling of plastics, alongside awareness campaigns, comprising a multipronged approach.

Beyond collective efforts, individual SeaBOS companies are also embracing innovative approaches to reduce plastic use and manage waste effectively. Thai Union, for instance, has developed reusable models to decrease reliance on single-use plastic packaging. They've also partnered with the Global Ghost Gear Initiative to manage and recover discarded fishing gear. Nissui is introducing non-Styrofoam packaging and enhancing fishing gear management rules using GGGI's "Best Practice Framework". Skretting has implemented compostable and post-consumer recycled packaging, underlining the possibilities of sustainable alternatives. Maruha Nichiro is advancing plastic reduction with a new production management system and strengthened buoy strength for aquaculture. Kyokuyo's approach includes diligent repair and maintenance to prevent plastic components of fishing nets and buoys from entering the ocean. CP Foods, have developed reusable Q-pass tanks for transporting shrimp post-larvae and redesigned packaging to reduce plastic usage, while also ensuring product safety and nutritional value. CP Foods is also focusing on reducing plastic use in their farm business and developing alternative packaging designs.

The Ocean Clean up

In plastic pollution mitigation, prevailing technologies primarily target larger plastics due to their tendency to accumulate in gyres at the centre of ocean basins, facilitating focused removal efforts. A prominent initiative in this space is The Ocean Cleanup, gaining attention from investors and researchers. Their primary focus centres on the Great Pacific Garbage Patch, utilising buoyant tubes spanning several kilometres. The technology aims to capture plastics ranging from tens of metres down to 1 cm, presenting a systematic approach to addressing ocean plastic pollution. While feasibility is yet to be conclusively determined, The Ocean clean up asserts that full deployment of their technology could remove 50% of the plastic within 5 years. The prototype has exhibited success at various small scales, with the first clean-up system launched in the Great Pacific Garbage Patch during the summer of 2018. Progress updates and milestones can be monitored here.

European Legislative measures: Ocean Plastic Reduction

The European Parliament has implemented the Single-Use Plastics Directive, targeting the ten most prevalent plastics, including commercial fishing gear, which constitutes 27% of litter in EU waters. Aligned with the broader EU Plastics Strategy, the directive aims to make all plastic packaging on the EU market reusable or recyclable by 2030. Starting December 2024, an "extended producer responsibility" approach will be enforced, requiring relevant companies to cover costs related to collecting, transporting, and recycling plastic fishing gear. These measures signify a calculated effort to reduce ocean plastic pollution.

6.2 Recycling Supply chain Plastics

The Sydney Fish Market Case Study

The Sydney Fish Market's plastic-neutral plan, initiated in January 2018, is a noteworthy case study within the broader landscape of sustainable supply chain practices. At its core, the plan incorporates a polystyrene processing machine, capable of annually recycling 150,000 fish boxes, thereby diverting the equivalent of 100 tonnes of polystyrene away from landfills. This intervention aligns with circular economy strategies and waste reduction within supply chains. Additionally, the market's decision to return blue fish crates to the manufacturer for recycling at the end of their 10-year life span exemplifies a commitment to closing the loop on material use, a fundamental principle in fostering sustainability.

6.3 Packaging Innovations

TomKat KoolPak® and Unicor®

TomKat Line Fish, a Queensland-based fishing business, introduced an alternative to traditional single-use polystyrene boxes in the seafood sector. Motivated by a commitment to environmentally responsible practices, Tom and Kath Long developed the TomKat KoolPak® as a sustainable solution. The TomKat KoolPak® is a reusable container designed for transporting and preserving perishable items, particularly premium reef fish. Boasting thermal features, this innovation aligns with principles of innovation and environmental consciousness. What sets it apart is its traceability throughout its life, offering a detailed tracking system for each component. Economically advantageous, the KoolPak demonstrates a cost reduction after just five uses. Its flat-pack design contributes to resource efficiency, diminishing transport costs and storage space requirements. Supported by an Au Industry Accelerating Commercialisation Grant, the KoolPak has transitioned from prototype to a technologically advanced product ready for commercial production, evident in its international patent applications. For further details, visit TomKat KoolPak®

Another Queensland based Australian Innovation is Unicor®, owned by Disruptive Packaging. Unicor® can replace conventional waxed cardboard and polystyrene packaging and is composed of between 65-70% calcium carbonate, which is 100% recyclable enabling closed-loop capabilities to create a circular economy. Currently catering markets across 3 continents – Australasia, South America and USA.

Biodegradable Plastics

The term 'biodegradable' in the context of plastics refers to materials that break down at accelerated rates compared to standard plastics. An example is 'oxo-degradable plastics' such as polyethylene (PE) or polypropylene (PP) where additives are incorporated to expedite the oxidation process, ultimately breaking down plastics into microplastics (Australian Bioplastics Association, nd). Several biodegradable plastics claim faster breakdown under specific environmental conditions, yet practical degradability under natural conditions remains uncertain. A recent study revealed biodegradable plastic bags were still intact after 3 years spent at sea or buried underground (Napper and Thompson, 2019) A primary challenge of biodegradable plastics is their reliance on specific waste management methods, often requiring separation from traditional recycling streams and processing in specialised compostable facilities. While not inherently unfeasible, these methods entail additional economic costs, particularly if the concentration of such plastics in the waste stream is low. Infrastructure redesign would be necessary for widespread implementation (Ritchie, 2018). In 2015, the United Nations Environment Programme (UNEP) released a study regarding the misconceptions, concerns and effects of biodegradable plastics. The report's findings suggested that using plastics labelled as 'biodegradable' would not lead to a substantial reduction in the amount of plastics entering the ocean or the threat of physical or chemical harm to marine systems based on the available scientific evidence (UNEP, 2015). These plastics cannot be certified compostable to Australian Standards and therefore are increasingly the focus of government legislators for removal from the Australian market (APCO, 2021c)

Biodegradable Plastics in Fishing Gear

To address the pollution caused by abandoned, lost, or discarded fishing gear (ALDFG), researchers are exploring the use of biodegradable plastic materials such as polybutylene succinate-*co*-adipate-co-terephthalate (PBSAT) in longline and gillnet fisheries (Cerbule et al., 2023; Gromaldo et al., 2019).

Grounded Packaging

Grounded Packaging has introduced a platform designed to facilitate the transition to sustainable materials in packaging. Through its end-to-end system, Grounded has streamlined packaging development and procurement, integrating sustainability data and certifications. Key features include Scope for material evaluation, Blueprint for design and manufacturing, Streamline for supply chain control, and Measure for sustainability data analysis. The incorporation of impact data into reporting frameworks improves the communication of sustainability efforts.

Recyclable Plastics

Traditional recycling methods often result in downcycling of plastics into lower- value products contributing to the accumulation of plastic waste. In response to this problem, a novel approach to plastic recycling is proposed, focusing on chemical recycling methods that allow plastics to be depolymerised and repolymerised without loss of function. Recent progress in polymer development showcases materials chemically recyclable to their original raw state, enabling the production of virgin plastics (Sardon & Dove, 2018). Scientists have demonstrated the synthesis of a plastic derived from a variant of γ-butyrolactone with mechanical properties akin to commercial counterparts, featuring infinite recyclability through chemical processes (Zhu et al., 2018). Furthermore, a study has found that by blending two enantiomerically pure polymers of opposite stereochemistry in a 1:1 stoichiometric ratio, superior materials could be obtained through Stereocomplexation. These materials have high melting temperatures significantly higher than their individual counterparts, making them suitable for high temperature applications (Stanford & Dove, 2010). This is a significant step towards a circular material economy where plastics never become waste but are instead continuously recycled into high value products. However further research and development are needed to improve the economic viability of chemical recycling processes and to design polymers with enhanced properties suitable for a wide range of applications (Sardon and Dove, 2018)

6.4 Research Innovations

Wax Worms and PE degradation

In 2017, scientists unveiled the wax worm's ability to degrade polyethylene (PE), a constituent of approximately 40% of global plastics. While PE is generally resistant to degradation, select bacteria or fungi have demonstrated slow degradation in previous instances. The wax worm's discovery exhibited comparatively faster rates of breakdown, albeit still gradual. In an experiment, 100 wax worms left on a PE plastic bag for 12 hours resulted in a 92-milligram degradation, representing about 3% of the plastic bag (Bombelli et al., 2017). Despite the slow and limited scale of degradation, the intention is not to scale up the utilisation of wax worms for plastic decomposition due to impracticality. Nevertheless, this discovery holds potential for identifying specific enzymes responsible for plastic breakdown. The proposed mechanism involves wax worms breaking down carbon-carbon bonds in PE, either internally or through the generation of a particular enzyme from their flora. This finding suggests the feasibility of industrial-scale production of the relevant enzyme or bacteria, providing a potential avenue for addressing plastic waste on a broader scale.

Bacterial degradation

Researchers in Japan made a significant discovery of *Ideonella sakaiensis* 201-F6, a bacterium with the ability to digest polyethylene terephthalate (PET), the material commonly used in single-use plastic bottles. This bacterium achieves plastic degradation by secreting an enzyme called PETase, which catalyses the breakdown of certain chemical bonds in PET. PETase, functioning as an accelerator in chemical reactions, facilitates the creation of smaller molecules that the bacteria can absorb as fuel or food, as they contain carbon (Yoshida et al., 2016). While this breakthrough has demonstrated success at laboratory scales, experts acknowledge that significant technological and scientific advancements are required before it can be scaled to make a substantial impact.

The economic feasibility and environmental trade-offs play a pivotal role in the development of recyclable materials and alternative solutions. Plastic's widespread use is attributed to its affordability, versatility, and relatively low energy, water, and land requirements for production. For alternatives to gain widespread acceptance across the seafood Industry, they must present breakthrough solutions that are economically competitive with existing methods. The key factors in addressing this challenge include the functionality, pricing, and scalability of innovations. (Ritchie et al., 2018)

The objectives of this study are to map and quantify use of plastic throughout the WRL supply chain. This involves investigating how plastics are employed, distributed, and handled at various stages of the supply chain. The study aims to seek ways to capture multiple sources of plastic use across the WRL supply chain to allow for targeted development, trial and implementation of plastic alternatives. This project will allow for greater knowledge and understanding of

(1) how and where plastic is used within the western rock lobster industry; and
(2) viable and environmentally friendly alternatives to the plastic currently in use.

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