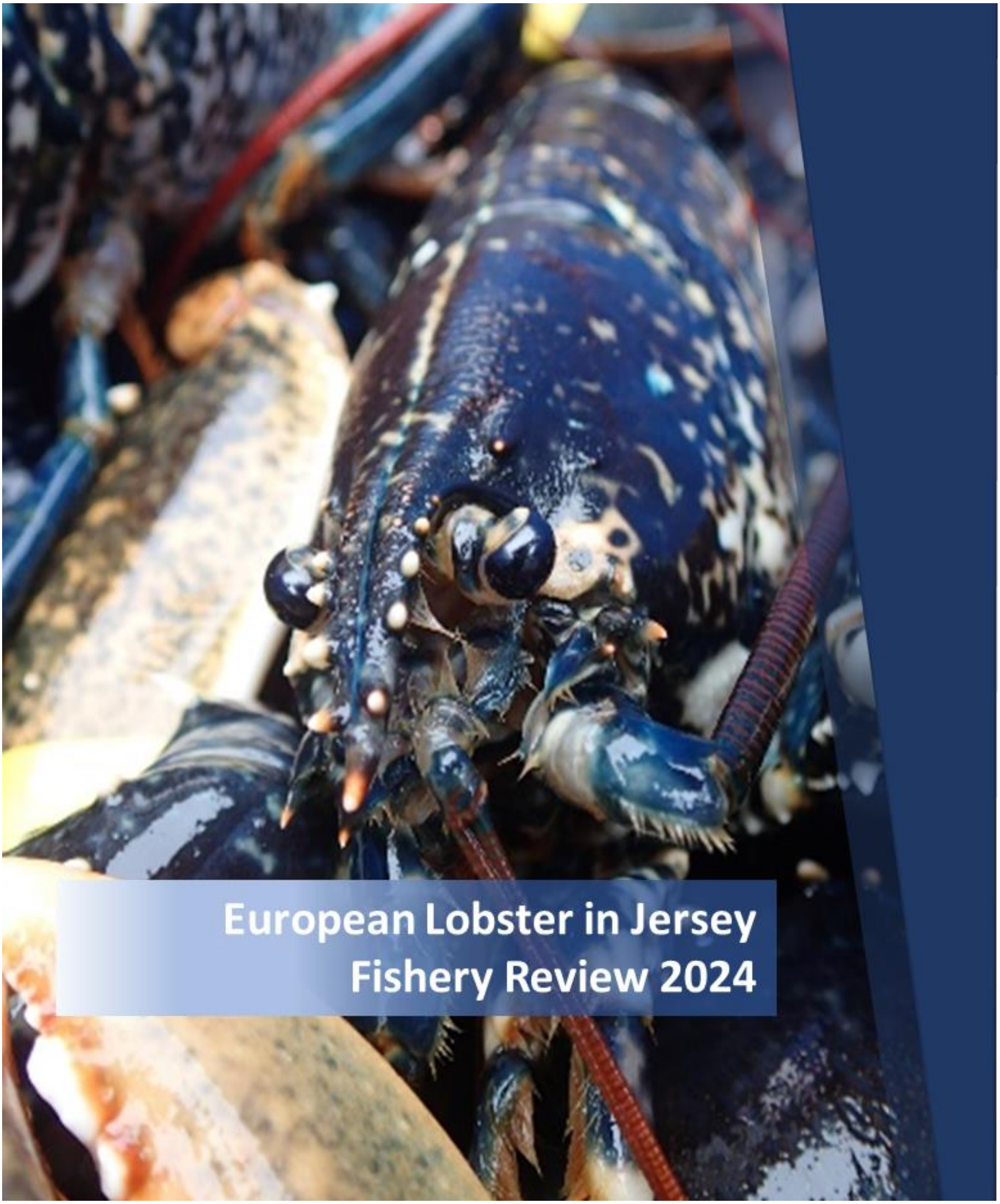

European Lobster in Jersey Fishery Review 2024

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European Lobster (*Homarus gammarus*) Fishery in Jersey

Fishery Review 2024

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Photograph on cover by Natalie Hold (European Lobster, *Homarus gammarus*)

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SUMMARY

In November 2023, the Jersey Government applied to Bangor University to have the Jersey Fishery reviewed to better understand their options for quantitative fisheries stock assessment. This report provides a review of the European lobster (*Homarus gammarus*) fishery in Jersey. It outlines a brief history of the fishery, current and recent management, data availability, and current stock assessment processes. We provide recommendations for improvements to data collection, and fisheries stock assessment.

The Fishery

The Jersey Lobster Fishery is a mainly artisanal pot-based fishery targeting European lobster (*Homarus gammarus*) based out of Jersey, Channel Islands. The fishery is managed by the Government of Jersey and targets a lobster stock that likely extends across several jurisdictions, including France (Normandy and Brittany). The fishery was previously governed through the Granville Bay Agreement with France until the United Kingdom's departure from the European Union. Post-Brexit, the current management framework is guided by the UK-EU Trade and Cooperation Agreement. Effort is capped through licence numbers, and by limiting the maximum numbers of pots to be fished by a vessel.

The Jersey lobster fishery makes up one part of the Unit of Assessment for the Marine Stewardship Council (MSC) Certified Normandy and Jersey Lobster Fishery. The fishery has been labelled as sustainable since 2011. Within the Jersey fishery there are some concerns regarding recent declines in catch, and catch rates, resulting in an effort to better understand the fishery stock dynamics.

Harvest Strategy

The fishery is covered by the MSC Certified Fishery Harvest Strategy, and the Harvest Control Rules are guided by standardised indices of abundance and landing rates within the joint Normandy and Jersey Fishery. The current weight-of-evidence stock assessment approach satisfies the criteria needed for the Harvest Control Rules (indice d'Abondance (IAS), and landings per unit effort calculations). The Harvest Strategy uses a traffic-light system to regulate fishing activity based on estimated stock abundance, and LPUE data.

Fishery Data

Consistent landings data are available from the commercial portion of the Jersey fishery (only Jersey-based vessels). Total fishing mortality is not accounted for, as there are few estimates of recreational catch, bycatch from trawl/dredge fisheries, and data from French vessels fishing within Jersey waters. A fishery-independent fixed-site survey collects data on undersized lobsters, and some length-frequency data are available for landed lobsters. There are 20 years of data from the independent survey, although the data are only collected in late spring, and summer providing an index of catch per pot for the fishery. The survey has been located over traditional inshore fishing grounds, however recent expansion of commercial fishing by some boats into deeper waters shows larger lobsters being landed from this section of the fleet in recent years that is not replicated in

the historical survey locations. The landings length-frequency data have been collected since 2018, however the numbers of lobsters measured is low in comparison to the total landings for the fishery.

Recent size-at-maturity studies have highlighted that the legal minimum length for European lobsters (87 mm – 90 mm across much of the range) is very close to being smaller than the size of a mature egg-bearing female. This has potential to lead the fishery towards recruitment overfishing.

Data are available for estimating necessary life history parameters such as weight-at-length and size of berried females, both of which provide insight into the population dynamics of the portion of the fishery the data cover. Other life history parameters (natural mortality, M, recruitment, and growth) require further data collection through tagging programs and additional surveys (commercial data collection from meshed pots, and greater spatial extent of the fixed-site survey).

Fishery Stock Assessment

The fishery is currently assessed using a weight-of-evidence approach using indices of abundance that are linked to the MSC Certified fishery's Harvest Control Rules (standardised LPUE). The LPUE standardisation process could be improved by including additional variables that affect catch rates, such as temperature, bathymetry data, gear type, and fine-scale spatial data.

Additional enhancements to the stock assessment should include assessing the length-frequency data from both the independent survey, and landings survey on an annual basis.

In terms of stock assessment modelling approaches, simple Catch-MSY methods should be investigated, using similar methods to those used in the MSC Certified fishery. When more length-frequency data are available for the commercial fishery, integrated modelling approaches that have been developed for crustaceans are worth investigating.

Key Recommendations:

To improve the Jersey Fishery stock assessment process, we have the following key recommendations:

1) Development of clear management objectives for the fishery with consideration for data and resource constraints.
2) Review the data and methods used within the current index of abundance (IAS) and standardised LPUE.
3) Review the current stock assessment models (Catch-MSY, SpiCT, and JABBA) and suitability for the fishery.
4) Use decision-support tools and simulation testing to identify potential new models for the fishery.
5) Link model outputs to the harvest control rules and the management objectives for the fishery.
6) Include capacity-building to ensure stock assessment methods are sustainable into the future.
7) Build on fishery-dependent data by designing commercial data collection scheme to improve length-frequency data from the fishery.

8) Improve fishery-independent data collection by investigating extending the fixed site survey to other locations, based on the spatial extent of the fishery.
9) Complete the above in collaboration with relevant stakeholders (e.g. commercial fishers).

Contents

1 Glossary of Terms

Abundance Index (Indice d'Abondance - IAS)

A measure used to estimate the number of fish or other marine species in a given area, based on data from surveys or catch records.

Artisanal Fishery

A small-scale fishery that typically uses traditional fishing methods and practices. It can involves fishing only for local consumption and operates with minimal technology and capital investment.

Berried female

A female lobster carrying eggs attached to her abdomen. In lobsters, these eggs are relatively large, visible and protected by the female until they hatch.

Bycatch

Non-target species that are unintentionally caught while fishing for other species. Bycatch can include fish, invertebrates, and other marine animals.

Catch Per Unit Effort (CPUE)

Catch obtained (in weight or number) per unit of fishing effort (e.g., per number of pot-lifts). CPUE is often used as an indicator of fish abundance as it is related to the biomass of available fish.

Effort control

Management measures that regulate the amount of fishing effort applied to a fishery, such as limiting the number of fishing vessels, days at sea, or gear used.

Fish

Fish are animals that are targeted by commercial and recreational fisheries. For the purposes of this report, fish and lobster can be used interchangeably.

Fishery-dependent data

Data collected directly from commercial and recreational fisheries, including catch records, fishing effort, and biological samples from landed catches.

Fishery-independent data

Data collected from scientific surveys that are independent of commercial fishing activities. These surveys often use standardised methods to estimate the abundance and distribution of fish.

Harvest Control Rule (HCR)

A pre-determined set of guidelines used to manage fishing activity based on the status of the fish stock. HCRs help ensure sustainable fishing practices by adjusting effort and catch limits according to outputs from stock assessments.

Integrated Stock Assessment Model

A comprehensive approach to stock assessment that combines multiple sources of data, such as fishery-dependent and fishery-independent data, into a single model that provides an analogy for the population dynamics of a stock. An integrated modelling approach helps improve the accuracy and reliability of stock assessments by providing a more complete picture of the fish population dynamics and how they respond to fishing pressure. Integrated models are usually either 'length' or 'age' based, depending on data availability. Most crustacean integrated modelling approaches are length-based as there is little information on lobster age, and how this relates to growth.

Landings Per Unit Effort (LPUE)

Landings (in weight or number) per unit of fishing effort (e.g., per number of pot-lifts). CPUE is often used as an indicator of fish abundance as it is related to the biomass of available fish.

Length-frequency data

Data that represent the distribution of lengths of individuals in a fish population. These data are used to assess length structure of the population through time, and the impact of fishing on different size classes.

Marine Stewardship Council (MSC) Certification

An international certification program that recognizes sustainable fishing practices. Fisheries that meet MSC standards are considered to be well-managed and sustainable.

Maximum Sustainable Yield (MSY)

The greatest long-term catch that can be taken from a fish stock under current prevailing environmental and fishery conditions. At the biomass level to maintain MSY (B_{MSY}), the population is maintained at the population size that will maintain the maximum growth rate by fishing the 'surplus production' or the biomass above B_{MSY}.

Natural Mortality (M)

The rate at which fish die due to natural causes, such as predation, disease, or old age, rather than fishing.

Pot-lift

The act of lifting or checking a pot for lobsters. Pot-lifts are used as a measure of effort in lobster fisheries, as they provide a more accurate estimate of effort compared to raw pot numbers on a vessel.

Recruitment

The process by which juvenile fish or invertebrates survive to join the adult population. Recruitment rates are crucial for understanding the sustainability and replenishment of fish stocks.

Size-at-maturity

The size at which individuals of a species reach sexual maturity and can reproduce. This size is important for setting legal minimum sizes to ensure that individuals have a chance to reproduce before being caught.

Standardised CPUE or LPUE

Standardised CPUE or LPUE is a metric used in fisheries science as a harvest control rule, and as an index of abundance. Standardisation of CPUE involves adjusting the raw CPUE (e.g. kg/pot-lift) to remove the effect of variation due to changing effort (number of pots, number of active vessels) or environmental variables that are known to have an impact on stock biomass, and availability to fishing gear. Standardising CPUE is usually obtained through model-fitting using Generalised Linear Models (GLMs), although other methods are possible.

Stock assessment

The process of collecting and analysing biological and fishery data to estimate the status of a fish stock. Stock assessments inform management decisions to ensure sustainable fishing practices.

Stock-recruitment relationship

The relationship between the biomass or size of the spawning stock (mature adults), or egg production levels, and the number of juvenile lobsters that are recruited into the fishery. Stock recruitment relationships are critical in understanding how spawning stock size will impact recruitment levels, and therefore the levels at which a population can be fished to without negatively impacting on the stock-recruitment relationship.

Surplus production

The proportion of the stock biomass that exceeds the amount required to maintain the stock at B_{MSY}. This can be harvested without depleting the stock. Surplus production helps determine maximum sustainable yield (MSY).

Total Allowable Catch (TAC)

The maximum quantity of a particular species that can be caught within a specified period, usually a year. TACs are set to prevent overfishing and ensure sustainable fish stocks.

V-Notching

A conservation practice where a V-shaped notch is cut into the tail of a female lobster to indicate that it is a breeding individual. V-notched lobsters are protected and must be released if caught.

2 Jersey's European Lobster Fishery

2.1 Fishery history and management

The European lobster (*Homarus gammarus*) fishery in Jersey (hereafter, the fishery) is part of a cross-jurisdictional, mainly artisanal fishery made up of approximately 130 boats. The Jersey portion of the fishery is managed by the Government of Jersey, a Crown Dependency of the United Kingdom. Historically the fishery has also been managed through cross-jurisdictional agreements, including the Granville Bay Agreement which was dissolved when the United Kingdom left the European Union.

The Granville Bay Treaty provided for co-management of marine resources between Jersey and France, due to the close nature of their territorial waters. Figure 1 shows the ICES statistical rectangles that are relevant to this fishery (Figure 1), while Figure 2 outlines the territorial limits and relevant agreements and fishing rights outlined within the Granville Bay Treaty (Figure 2).

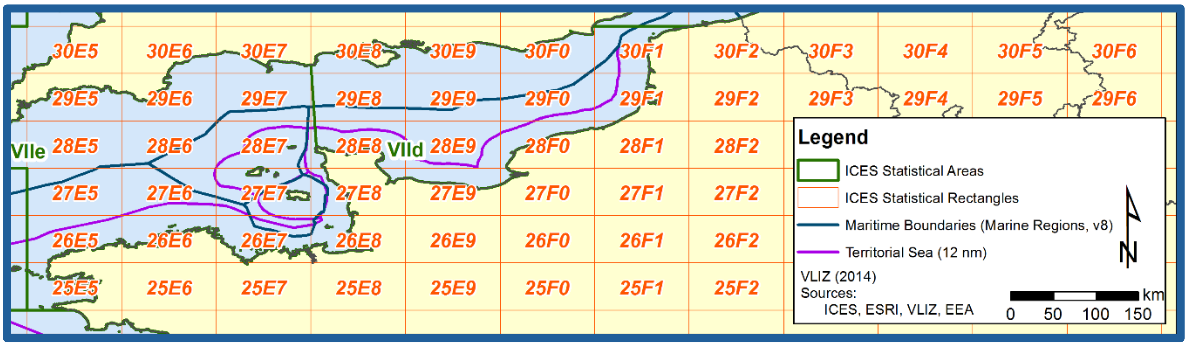

Figure 1: Map showing the ICES statistical rectangles that the Jersey lobster fishery operates within (28E7; 28E8; 27E8; 27E7; 26E7; 26E8) in the context of Jersey's territorial sea boundary (12 nautical miles), and France's territorial sea (Cropped from source: www.marineregions.org/maps.php?album=3753&pic=107478).

The Normandy and Jersey fishery comprises of a solely French fishery (North and West Cotentin), a solely Jersey fishery (Jersey), and a shared fishery between France and Jersey (Granville Bay). Prior to the United Kingdom (and hence Jersey, as a Crown Dependency) leaving the European Union (EU), management of the fishery was implemented through the Granville Bay Agreement and the London Fisheries Convention (UK Government: https://www.gov.uk/guidance/united-kingdom-single-issuing-authority-uksia#crown-dependencies). The Granville Bay Agreement dissolved in February 2020, when the UK left the EU, however the fishery has continued to be managed without any formal legislative binding agreements with France. Any changes to fisheries management in Jersey waters by the Government of Jersey, that affect French-flagged vessels must be notified via the UK-EU Trade and Cooperation Agreement (TCA) terms.

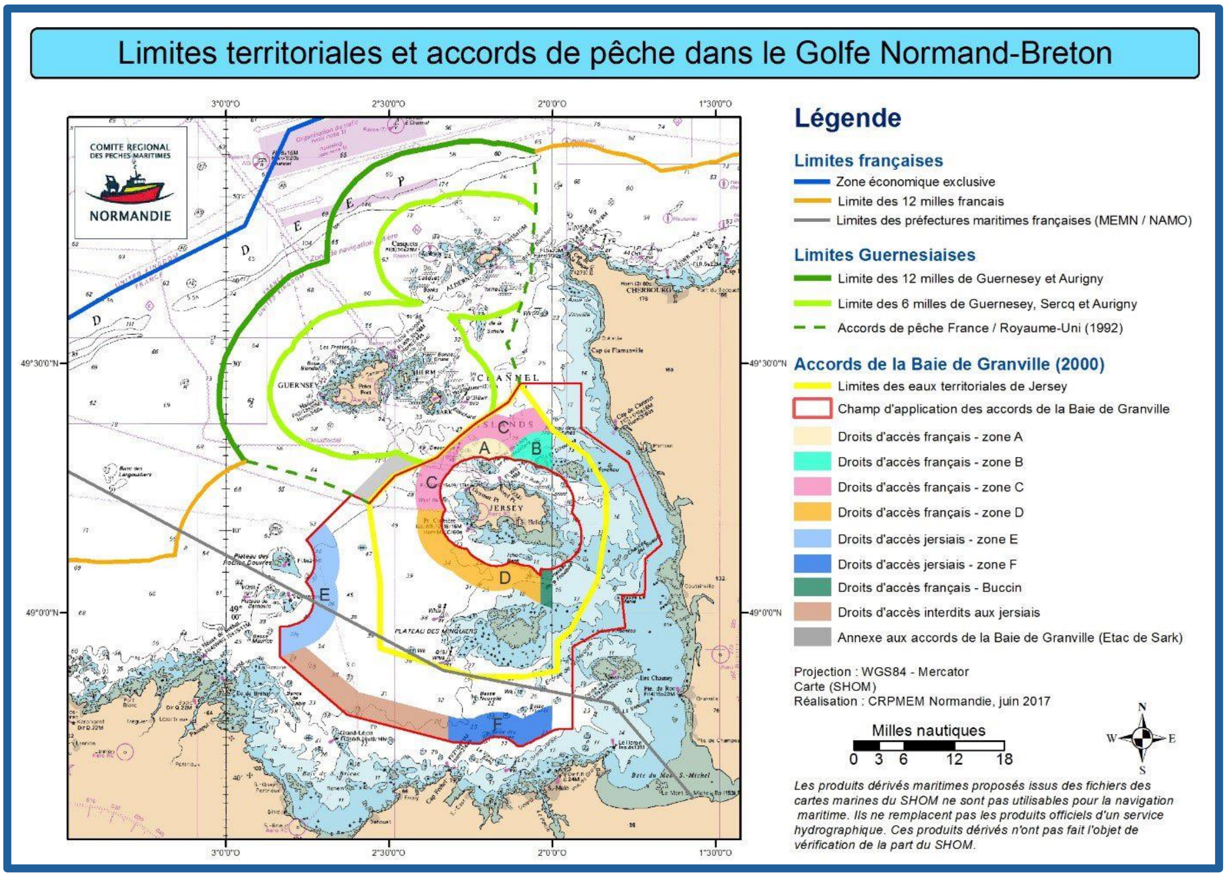

FIgure 2: Territorial limits and fishing agreements within the Gulf of Normandy-Breton, including those under the Granville Bay agreement (2000): Source: CRPMEM Normandie.

Under article 502 of the current TCA, the EU and Jersey have granted each other access to fishing grounds within their respective territorial waters. The access reflects prior fishing activity that was carried out by qualifying vessels from 1st February 2017 to 31st January 2020 (the reference period). Qualifying vessels are those that can demonstrate they fished in the fishery on at least 11 days in any of the 12-month periods within the reference period.

Implementation of access to relevant waters was carried out in two stages. Licences were initially issued to relevant EU vessels in 2021. From 1st February 2023, further conditions were added to licences to reflect conditions under the TCA. These include licence arrangements for licencing any replacement vessels and engines.

Within the combined Jersey-Normandy fishery, approximately 270-290 tonnes of lobster are landed annually[1]. There are 66 French vessels that are licenced to fish within Jersey's waters, based on reported fishing gear of pots and traps (FAO Fishing Gear Type "FPO"). Of these, 38 vessels are under 10 m in length, and the remaining 22 are between 10 – 12 m (UK Government: https://www.gov.uk/guidance/united-kingdom-single-issuing-authority-uksia#crown-dependencies). Licencing for Jersey's fishing fleet is controlled by the Government of Jersey. Boats must hold a Jersey Fishing Boat licence to fish for lobster.

In total, there are 74 vessels that have been included in the Unit of Certification for the MSC-certified fishery[1]. Only 3 vessels are over 10 m in length, and all vessels are under 12 m in length. There were reciprocal agreements for the six and 12 nautical mile boundaries for both French and Jersey licenced vessels to fish within each other's jurisdictional boundaries (Figure 2) under the Granville Bay Treaty. However, since it's dissolution, Jersey boats fish within the three nautical mile zone, and both French and Jersey vessels can fish in waters beyond this area, although only five active Jersey vessels have access to French waters currently.

2.2 Marine Stewardship Council Certification

The fishery in Jersey is certified as sustainable under the Marine Stewardship Council (MSC) certification system as part of a cross-jurisdictional fishery covering the North and West Cotentin (Normandy, France), Jersey (Crown Dependency), and Granville Bay (shared fishery between Normandy and Jersey). The fishery has held MSC accreditation since June 2011, and recently underwent re-certification in 2022-2023. The fishery is certified until November 2028 [1]. Five vessels that fish within Guernsey waters, but land in Jersey and Normandy (in Jersey this is St. Peter Port) were removed from the Unit of Certification to assure that all lobsters landed from vessels in the MSC Certified fishery are traced back to the geographical extent of the Jersey and Normandy fishery [1].

2.3 Harvest Strategy

The Joint Management Committee for the MSC Certified fishery (Jersey and Normandy) manages the entire fishery using a management strategy that is determined by the state of the stock in relation to the observed index of abundance (idice d'abondance, IAS) and the raw landings per unit effort (LPUE) calculated across the entire multi-jurisdictional fishery [1].

The harvest strategy for the combined fishery includes regulations that are relevant to all boats within the fishery. The fishery is managed using effort control rules primarily: Jersey boats are allowed to use a maximum of 1000 pots per vessel – the exact number is determined by the size of the vessel. A minimum landing size of 87 mm currently applies to both male and female lobsters at the time of writing in June 2024. However this is due to be increase by 1 mm a year reaching 90 mm carapace length in August 2026. There are no regulations relating to egg-bearing (berried) females or V-notched females. There is no limit on the number of pot-lifts per trip.

Harvest Control Rules are provided within the reduced fishery MSC assessment report for 2016,[2] and follow a traffic light system: when the fishery is in the green zone (and the IAS is > 1), the fishery is in a good state; when the fishery is in the orange zone (IAS is < 1 but LPUE > 6 kg per 100 pot-lifts the fishery is in 'alert' state; when the fishery is in the red zone (LPUE < 6 kg per 100 pots) the fishery is in a 'danger' zone, and various management levers can be used in the orange and red zones. For example, if the fishery reaches the red zone, the legal minimum size will raise to 90 mm (from 87 mm), and there is a possibility of introducing a legal maximum size of 120 mm (Table 1, taken from Figure 15 in [1]; translated by G. Phillips from French).

There is little published information on how the IAS is calculated, and how this differs from the standardised LPUE. Moving forward, it would be beneficial to understand how this abundance index is calculated, to understand how representative it is of the population.

Table 1: Harvest Control Rules for the joint Normandy and Jersey MSC Certified lobster fishery

State of the Joint Fishery	**Measurement**	**Harvest Control Rule**
Green Zone (Good State)	Abundance index > 1	Current fishery management maintained. In Normandy, this includes a continual reduction in the number of licences through fewer reallocation when licences are retired. If a systematic decline in the abundance index is observed, without dropping below 1, precautionary management measures are taken.
Orange Zone (Alert Zone)	Abundance index < 1 LPUE > 6 kg / 100 pots	Immediate review of other indices of stock status. These are: • CPUE from survey • Size-structure from surveys and landings • Characteristics of reproductive females, and • Indices of recruitment from surveys. If these indices are concerning, management action is taken immediately. If there are no problems identified, the current management regime continues for one year before reviewing. Management actions may include a reduction in the number of pots (by type or fishing zone); changes to proportions of parlour pots permitted in the fishery; licence reductions; measures against 'ghost fishing'; and other potential measurements.
Red Zone (Danger Zone)	LPUE < 6 kg / 100 pots	In addition to the effort restrictions in the orange zone, biological management actions will be implemented. These may include an increase in the minimum landing size; introduction of maximum landing size; ban on landing lobsters with no claws; ban on landing berried females; closed seasons; ban on the landing of V-notched lobsters; and/or additional closed areas.

2.4 Gear

The fishery uses pots to catch lobster. There are two major variations of pots – inkwell and parlour pots. Traditional creel pots and 'D-pots' are also recorded as being used within the Jersey Government, (2022). Effort is managed in Normandy and Brittany using effort controls, with a maximum number of licences available (these are mixed species licences covering lobster, spider crab, and brown crab), and a maximum number of pots per vessel, based on vessel size. Jersey vessel numbers are only limited by maximum numbers of UK licences available, and new vessels can join the Jersey lobster fishery if they have a valid UK fishing licence.

Inkwell pots are simple pots that are usually round with an opening (neck) in the top to allow lobsters to enter. Parlour pots are cuboid in shape and have two separate chambers that trap the lobster inside. It is mandatory in Jersey legislation that parlour pots have an escape gap in the parlour end measuring 79mm x 44mm. This allows juvenile lobsters and associated by-catch species to escape and avoid predation. Parlour pots are restricted in most of Normandy waters. Specifically, parlour pots are banned from the offshore reef fishing grounds 'Les Minquiers' and 'Les Ecrehous' in Jersey territorial waters as this is an important location for the recruitment of juvenile lobsters (Figure 3 in [3]).

Pots are generally deployed in 'strings' of 12-50 pots and vessels are permitted to use a maximum of 1000 pots per vessel, however this is linked to operational restrictions (e.g. size of vessel may limit the number of pots that are practicable). The gear is highly selective, and therefore secondary bycatch species are limited to spider crab and brown crab, both of which are commercially important species. Additional species such as catsharks, wrasse, and bream are also caught in pots, but not reported, as the fish are used immediately as bait, or returned to the water, alive (*pers comms.* Government of Jersey). There is some concern regarding brown crab population decline in recent years [4], despite fishery measures and strategies to reduce bycatch being in place for several decades. Additionally, there is limited data collection relating to bait use, and sourcing of bait, which is important to quantify if ecosystem-based fisheries management is an aim for the fishery.

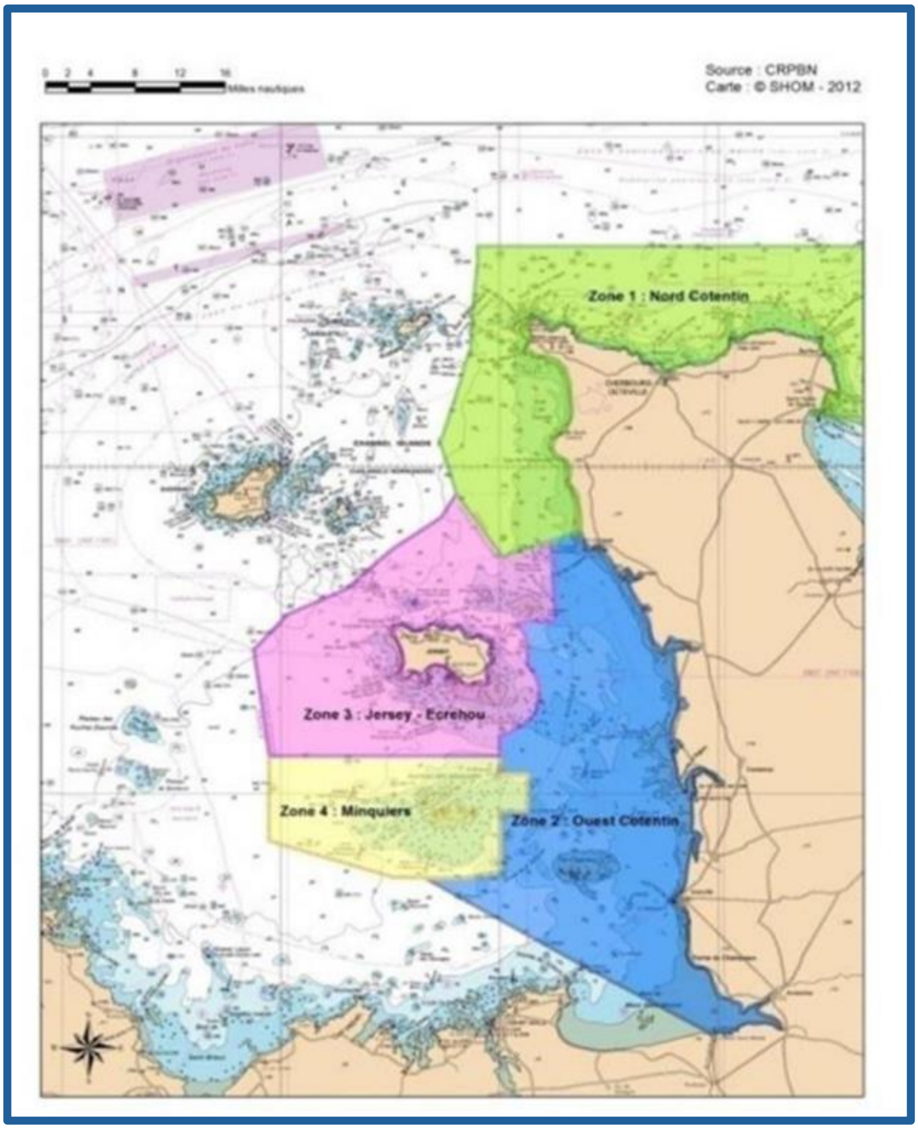

Figure 3: Fishery assessment zones for the Jersey and Normandy lobster fishery. Parlour pots are banned in the National Park Protect Zone in Les Minquiers due to this area being important habitat for juvenile lobsters.

3 General Ecology and Biology

3.1 Taxonomy and distribution

The European lobster (FR: homard), *Homarus gammarus* L. (hereafter, lobster), is a large, commercially important decapod (10 pairs of limbs) crustacean from the Nephropidae family that is distributed across the Eastern Atlantic, Mediterranean and Black Sea, from the north coast of Africa to northern Norway (69°N - 29°N and 28°W - 32°W). Lobsters are found in most habitats, including the continental shelf, down to depths of 150 m, however they are more commonly found to inhabit shallow coastal waters from the intertidal region to 50 m depth. Lobsters are primarily found within rocky habitats that provide shelter in crevices, overhangs, and cracks[5]

Homarid lobsters include *Homarus gammarus* and *H. americanus* (American Lobster) are considered 'clawed' lobsters, as the first pair of limbs are modified into specialised claws. One claw is large and blunt and used for crushing (also called the 'crusher') and the other is sharper and used for 'slicing'. Lobsters swim by contracting their strong abdominal muscles that run under their abdomen towards their tail.

3.2 Population structure

Genetic studies of European lobster suggest several distinct genetic clusters including the Mediterranean; eastern North Sea (Norway, Denmark); Skagerrak; and western North Sea, UK, Ireland, France, and northern Spain [6–8] . The pelagic larval phase of lobsters may serve to connect populations, however while larval connectivity may be able to homogenise genetic frequencies at sea scales, oceanographic modelling (Unpublished data) and research into adult migrations suggest demographic population connectivity may be at a finer scale.

Adult lobster populations are generally localised with lobsters occupying home ranges in the order of hundreds of square meters, on time scales of months to years, although some smaller percentages of adults do undertake larger scale movements [9–11]. In general, fine-scale stock structure around Jersey, Normandy and northern Brittany for lobsters is not well understood, however Granville Bay and the Island of Jersey have generally shallow waters (< 30-40m) with a deeper channel separating Jersey from Guernsey (40-50m) and then deeper waters out into the English channel. In addition, Jersey is separated from the north (Guernsey and possibly from North Contenin) by a tidal front [12] and then residual flow is anticlockwise around Jersey [12] suggesting possible larval retention. The unit of assessment in the MSC certified fishery includes North Contenin (Figure 3), although this area may be less well connected to Jersey than West Contenin, based on the bathymetry preferences of adults and hydrological characteristics that may limit larval transport. Suitable hard substrate and coarse sediment with offshore reefs extend into Normandy and Brittany waters (Figure 3). It is therefore likely that Jersey waters share lobster stocks with West Contenin and the north coast of Brittany, with more limited connectivity to the north.

3.3 Biology and life history

As with other crustaceans, lobsters grow by undergoing a seasonal moult, and shedding their exoskeleton to allow for an increase in body length and weight. European lobsters exhibit sex-specific moulting and incremental growth patterns, with female lobsters maturing between 82-92 mm carapace length (CL)[13], at approximately 5 – 7 years old, and male lobsters have been shown to mature at slightly smaller sizes than females in more northern latitudes [14]. Male lobsters take advantage of newly moulted soft females, and are thought to mate with them early in the boreal summer following which eggs are extruded onto the female pleopods under the abdomen in late summer to early autumn every year. Studies specific to the reproduction cycle in Jersey waters may provide a better understanding of these patterns in local waters. At this point, females are 'berried' or 'egg-bearing'. Female lobsters can carry up to 30,000 eggs depending on their size, and location [15–17].

Eggs are carried by the female for approximately 9-10 months[18] until the boreal spring the following year, when the larvae hatch and start their pelagic larval phase. The European lobster has a pelagic larval phase that requires *c*. 250-degree days to settlement. Females hatch eggs in early summer in UK waters and so at a temperature of ~15°C the larval duration would be around 16 days [19–22]. During this pelagic larval phase, the larvae moult three times while feeding on phytoplankton and zooplankton, and during the fourth moult, they metamorphose into small post-larvae lobsters and settle in the benthic substrate. The location of their settlement is not known and attempts to sample puerulus within European lobster fisheries has up until now been unsuccessful, however it is known that the 'Les Minquiers' region within the fishery is an important juvenile lobster habitat.

From laboratory experiments, it is known that once settled, juveniles bury themselves within the substrate[23] where they spend approximately two years, without much movement. At approximately 15 mm CL they will leave their burrows and move to rocky crevices, cracks, and cobbled surfaces to begin life as a juvenile, and then adult lobster[24,25]. It is not until they reach around 40 mm CL (presumably after several moults), that they are found within commercial lobster pots or traps.

Decapod crustaceans do not have known deposition markers that can be used to provide a reliable source of data for ageing individuals, unlike teleosts. There has been one study into the accumulation of lipofuscin in the eyestalk of European lobsters (this structure is not shed during the annual moult) that suggests females may grow to approximately 72 years, and males to 42 years [26]. Other destructive ageing methods have potential for example counting 'growth' rings in gastric mills of American lobsters, *Homarus americanus* [27]; and there is some progress in non-destructive DNA-based methods such as DNA methylation-based techniques[28]. It should be noted that considerable knowledge gaps still exist regarding the accuracy of DNA methylation (e.g. do all tissues 'age' at the same rate?) and data are still required to be compared to 'known' age individuals to understand the accuracy of modelled ages. This is challenging in crustaceans, where spatial differences in growth, and onset of maturity can be considerable [29–31].

Using ecological niche modelling, European lobsters are predicted to be mainly found close to rocky substrate (mean distance to rock of 30 m), in topographical depressions in the seabed at shallow depths (mean depth = 37 m), in sheltered areas (wave flux 0.3 kW h m^{-1} +/- 0.09) [32]. Research has shown colonization of artificial reef structures within sandy or otherwise unsuitable habitat e.g. offshore wind scour protection[33 33].

Adults do not tend to move much once mature, and multiple tagging studies have shown that most re-captured lobsters are found within a few meters and generally less than 3 km of their initial capture location, even with time at liberty over multiple years[9,34–38]. Acoustic studies show that lobsters have a home range in the order of a few hundred to a thousand square meters that they explore [10,33], generally through diel activity [39], for feeding and mating, returning daily to their protective resting habitat. Male lobsters have been shown to have slightly larger home ranges than females, with both sexes showing larger home ranges in spring compared to autumn, although longer duration of movements and overall greater movement is seen in Autumn [10]. A small minority of adults do travel long distances – over 10s of kilometres [37].

European lobster diet varies throughout the different life stages. Larvae feed on phytoplankton and zooplankton. Adult lobsters are nocturnal predators, primarily feeding on other benthic invertebrates such as malacostracan crustaceans, gastropod molluscs, and polychaete annelids; but their diet is also known to include carrion, echinoderms, lamellibranchs and plant matter [40].

As pelagic planktonic larvae, lobsters are highly susceptible to predation by schooling fin fish such as cod and herring, and larger pelagic fish such as basking sharks. Settlement is likely to be highly dependent on specific variables, as in other decapod crustaceans, for example spiny lobsters [41,42]. Once settled, lobsters are vulnerable to predation by other predatory fishes, larger lobsters, and crustaceans. As large adult lobsters, they are unlikely to be predated on by any other organisms other than humans.

4 Fisheries Stock Assessment and Harvest Strategy

Fisheries stock assessment is broad and encompasses a range of methods and approaches. The overarching aim of a stock assessment is to assess the status of a fish population. We have provided a glossary with some definitions of key terms that will be used throughout the rest of the report (pages 7-9). Stock assessment makes up one aspect of a harvest strategy. Harvest strategies also traditionally include data collection, and management measures, thereby encompassing the entire cycle of fisheries management (data collection, data analyses, management action). [43,44] The method of stock assessment employed depends on data availability, the biology and ecology of the species being assessed, and the fleet composition and dynamics (e.g. who is accessing the stock, when are they accessing it, and how much of the stock are they accessing and or taking). There is also an element of bias introduced relating to the experience of the stock assessment scientist, and the management framework within which the assessment lies (e.g. it may not be practicable to collect sufficient data to do the best practice analyses).

In this report we will focus on the first two elements of harvest strategy – the data collection, and data analyses.

4.1 Quantitative stock assessment

Quantitative stock assessment runs along a continuum from "data-limited" to "data-moderate" to "data-rich" depending on data availability for a fish stock. A great recent resource for fisheries stock assessment modelling can be found at the webpages of the Centre for the Advancement of Population Assessment Methodology (CAPAM, https://www.capamresearch.org/current-projects/Good-practices). Data-rich assessment would use time series of data from all relevant fleets that includes catch, effort, growth parameters, size-at-age, or weight-at-length data from fishery dependent and fishery independent sources, and population or stock estimates for natural mortality, recruitment, and gear selectivity at a minimum. Data need to be collected for time scales relevant to the lifespan of the fish species (e.g. longer time series are required for long-lived species). Data are then usually used in integrated stock assessment models, where the information from different sources is integrated in a model to provide estimated outputs for relevant species-specific stock parameters such as biomass levels, or egg production levels. These outputs are then usually used in harvest control rule tools that provide recommended limits for the next seasons' catch to fishery managers.

In contrast, data-limited methods rely on minimal data, such as catch, and an understanding of fish population dynamics, and basic fisheries science, for example the relationship between catch, maximum sustainable yield (MSY), the stock carrying capacity or virgin biomass (B_0), and the current estimated biomass ($B_{current}$). Outputs from catch-MSY methods can also be incorporated into harvest control rule tools to provide fishery managers with recommended limits on catch for the next season. There are many data-limited methods, and good practices for data-limited assessments should be applied to all stocks, regardless of data availability[45].

Although the 'gold-standard' for fisheries stock assessment would be an integrated stock assessment modelling framework relevant to the fish (e.g. based on the data available), quantitative models need only to be as complex as the harvest control rules require – e.g. if the fishery is managed using catch per unit effort (CPUE), a fully-integrated model is not required.

In the rest of this report, we outline the current stock assessment approach that the Jersey Lobster fishery has implemented, review the data collection within the fishery, and provide recommendations relating to future stock assessment work, and the changes to data collection that may be required.

5 Current Stock Assessment Approach

Currently, the Jersey lobster fishery is assessed using a weight-of-evidence approach. The Jersey portion of the stock is also assessed as part of the Normandy and Jersey Lobster Fishery MSC Unit of Assessment, using separate data analyses.

The weight-of-evidence approach for the Jersey fishery includes several metrics, which are analysed annually and presented as part of the Jersey Marine Resources Report [3]. The metrics include:

- Commercial landings (tonne) for the entire fishery, and for several landing ports
- Commercial effort (pot-lifts) for the entire fishery, and for several landing ports
- Raw unstandardised landings per unit effort (kg / 100 pot-lifts)
- Standardised landings per unit effort (kg / 100 pot-lifts), using data from a 'reference fleet' in the year 2007.
- Number of licences used to fish the stock, and number of licences over time in the fishery.

The Normandy and Jersey fishery analyses also include:

- Analyses of catch trends (landings data) for Normandy and Jersey separately
- Raw unstandardised landings per unit effort (kg / 100 pot-lifts) for Normandy and Jersey separately
- Standardised abundance index (indice d'abonndance, IAS) for the combined fisheries (whole stock), using a generalised linear model (GLM)
- Preliminary stock assessment modelling using different scenarios for the whole stock:
  - Catch-MSY model fitted to lobster landings, and IAS data.
  - Stochastic surplus production model in continuous time (SpiCT model)
  - Just Another Bayesian Biomass Assessment (JABBA)

5.1 Stock assessment review and focus for this report

There has been a recent peer review of the stock assessment that was completed for the MSC Certification [46]. The stock assessment review suggested that a 'fully documented benchmark stock assessment' is a necessary next step to direct future developments of the harvest strategy for the whole stock.

In this report, we review the current stock assessment approach for the Jersey Lobster fishery, by outlining the data collected by the fishery from all sources, reviewing the current data analyses that contribute to the stock assessment, and suggest future data collection that would allow the testing of various integrated modelling techniques.

6 Fishery Data

There are several sources of data for the fishery. Jersey collects commercial landings data (accurate weight of landed lobsters), the total number of pots fished for each vessel on a given day, which is reported as 'pot-lift' data (number of times a pot is 'lifted' in a day). These data are collected only from Jersey-based vessels. Fishery data from French vessels are available, but not analysed by the Jersey Government. From 2023, French vessels fishing for lobsters in Jersey waters will submit logbook data in the same format as Jersey vessels. In January 2024, Jersey fishing vessels have been fitted with tracking devices which, when switched on in late 2024, will provide a more detailed effort signature for the fishery and allow for more detailed spatial information (such as the extent of the fishery).

Commercial landing data and catch have been collected for the Bay of Granville portion of the fishery since 1986. However, data are only used for stock assessment purposes after 2007, due to reports of unviability of earlier data [1].

6.1 Commercial catch and effort

Commercial landings (tonnes) for the fishery have been steadily declining after a peak in landings of 268 tonnes in 2011 (Figure 4). Landings remained steady between 2012-2017, at around 240 tonnes followed by a more dramatic decline. In 2020, low landing figures were attributed to poor winter weather conditions and the impacts of the COVID-19 pandemic. However, the UK leaving the European Union, and therefore a lack of market options, impacted landings in 2020-2021. Landings did not recover in 2022, however, despite exportation still being available to France.

Over the same period (2007 to 2022), raw LPUE (kg lobster per 1000 pot-lifts) has remained relatively stable, with a small up-tick in LPUE since 2020 (Figure 4). Commercial landings are concentrated in three areas: 26E7BG, 27E7BG and 27E7JE. The areas with the highest commercial landings over time (27E7BG and 27E7JE) both show declines in effort consistent with the entire Jersey fishery (Figure 5).

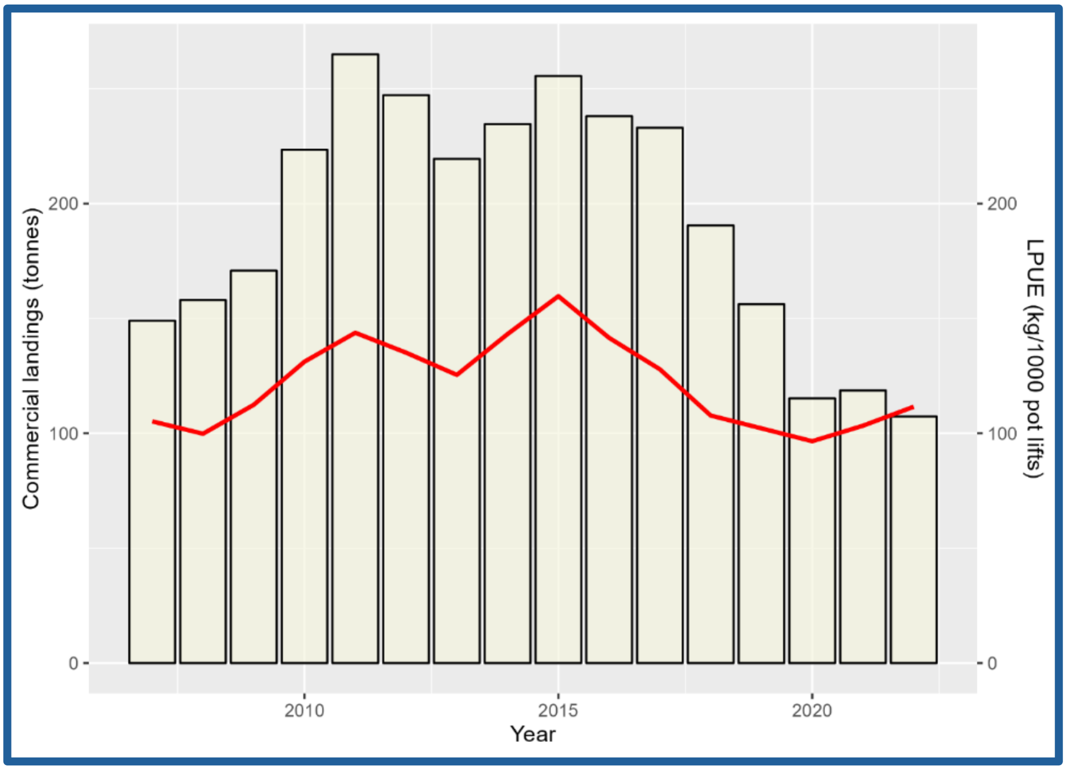

Figure 4: Commercial landings (tonnes, left hand axis) and raw landings per unit effort (kg / 1000 pot lifts, right hand axis) from 2007 -2022.

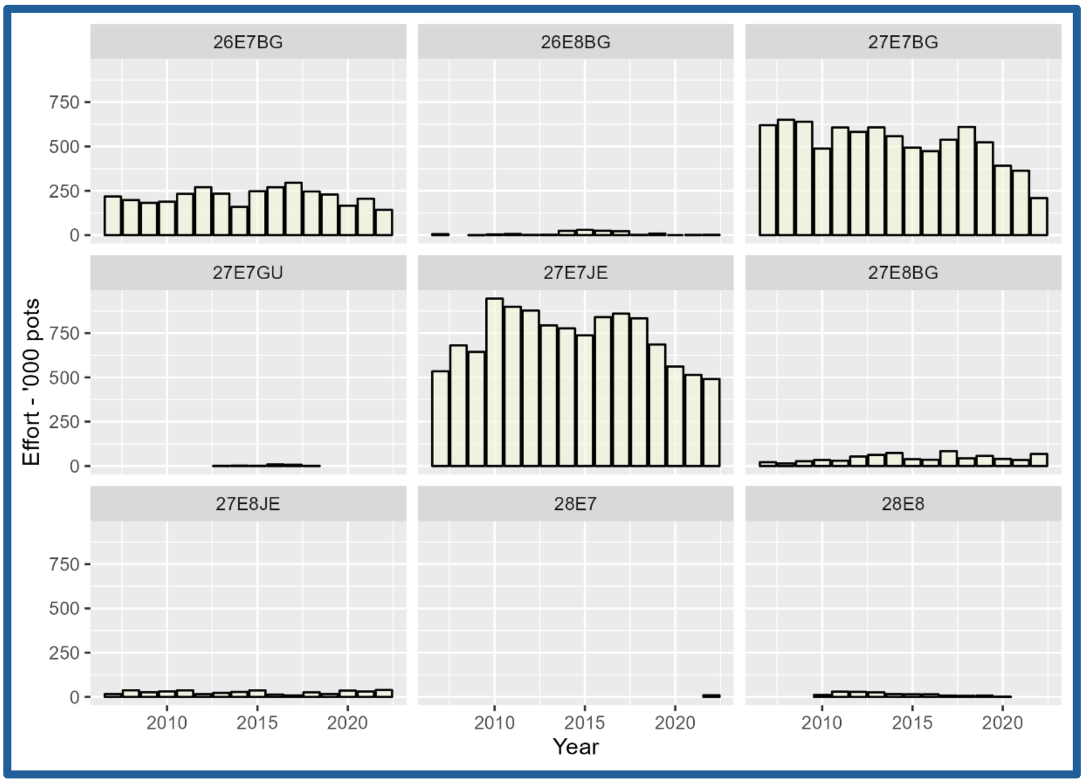

Figure 5: Commercial effort (‘000 pot-lifts) by ICES reporting area within the Jersey fishery. Effort is for all pot-types aggregated over a year.

Most of the catch is caught using parlour pots, which also displays a decrease in effort (‘000 pot-lifts) in recent years. The number of inkwell pots has remained steady since 2007 (Figure 6) reflecting the artisanal nature of the fishery.

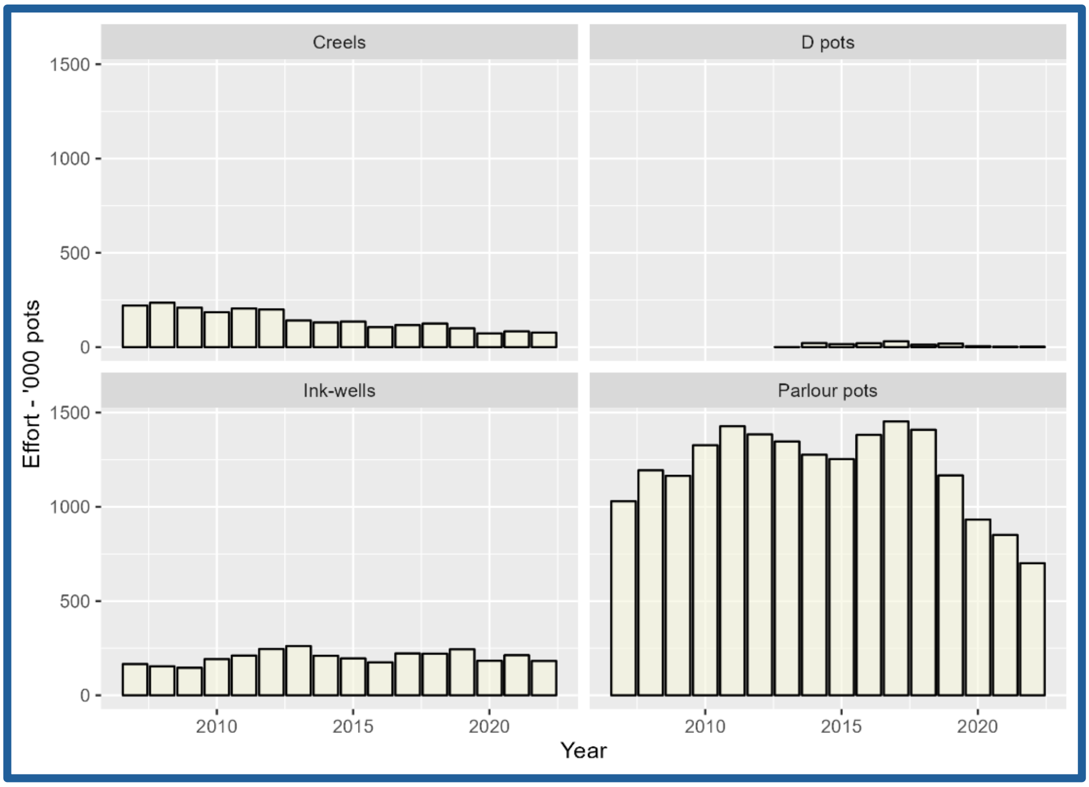

Figure 6: Effort ('000 pots) by pot-type as recorded in daily catch and effort logbooks to the Government of Jersey. Data are aggregated annually over all spatial reporting areas for the Jersey fishery.

Commercial logbook data includes daily catch and effort information, however standardised abundance indices for the stock are based on landings and total pot-lifts. In the MSC assessment for the joint Normandy and Jersey fishery, landings per unit of effort (LPUE) is standardised to include vessel ID and location using Generalised Linear Models (GLM), across the entire Normandy and Jersey fishery, and separately in the Jersey portion of the stock. Standardised LPUE figures and method were not available for review for this report, however prior reviews of the stock assessment [46] write that 'the methodology is sound and relevant for the fishery, in the light of the Harvest Control Rules'. The report recommends improvements to the standardised LPUE including testing alternative formulations of the GLM that use different link functions (they suggest using a negative binomial model); including pot type in the model (although this will require analysis of daily catch records and allocation to pot types, which may not be possible as fishers often use multiple gear types on one day (*pers. comms. Government of Jersey*)); and including additional potential sources of variation in catch rates (e.g. temperature, vessel types, bathymetry data). They also recommend attempting a calibration of standardised and unstandardised LPUE[46].

Including data on pot type used to catch lobsters will also improve the standardised LPUE as it will incorporate spatial and temporal closures to specific gear types (e.g. ban on use of parlour pots in Les Minquiers and other regions).

6.1.1 Recommendations for commercial data improvements

Current data collection is limited to accurate weights from landings data and linking this data to reported location of a vessel during a day of fishing. Data are limited to Jersey vessels, and data are difficult to access from French vessels that operate within the Jersey fishery. For accurate standardisation of catch rates or landing rates, the location of the catch should be recorded and then used in LPUE standardisation processes. This will allow for more detailed variables to be included within any LPUE standardisations, such as depth and water temperature.

As standardised CPUE or LPUE are important variables for the harvest control rules within the MSC fishery [1], it is important that the process of standardisation is thorough, and transparent. Methods should be available, and should undergo peer-review, through workshops with external scientists, or through relevant ICES working groups.

Collecting high-level spatial data would be useful to understand whether plateauing catch and effort metrics are due to fisher behaviour (e.g. chasing the stock is maintaining artificially high abundance estimates) and whether spatial depletion is occurring on a finer scale than is currently possible to assess. This is referred to as hyperstability. Hyperstability is when a fished population appears to be sustaining catch and catch rates, as neither are declining over time, however, on closer inspection, the stable catch and or catch rates are hiding fishers moving to new fishing grounds, and potentially sequentially depleting individual fishing grounds [47].

RECOMMENDATIONS

A key limitation of current fisheries dependant data is the lack of landings data from French vessels. These data will be essential for future stock assessment and efforts should be made to source the data from French colleagues. This will result in better estimates for total fishery-based mortality (F).

Standardisation of the LPUE metric would be beneficial, with the inclusion of variables such as season or month, area of capture, tidal state and vessel ID being used within a Generalised Linear Model, Spatial-temporal GLMM (e.g. VAST or sdmTMB) or other standardisation techniques to provide a more robust index for tracking trends and inferring stock status (Hoyle et al., 2024).

To do this it is recommended to:

Continue to collect daily commercial fishing data.

Collect daily numbers of lobsters caught.

Collect daily numbers of pot-lifts (or number of pots and the number of times the pots were set during a trip).

Collect pot type associated with daily numbers of lobsters caught.

Collect fine-scale data on location of fishing activity (via vessel monitoring systems, or through finer-scale spatial data than the ICES fishing rectangle, if possible).

6.2 Fishery independent catch and effort

An annual survey conducted in spring of each year since 2004 (no survey was completed in 2015), collects data on catch per pot, and extensive biological data e.g. sex, carapace length, reproductive state of females (berried or non-berried), weight, and width of carapace. Each year catch per pot lift (CPUE) is calculated for the survey and analysed internally within the Jersey fishery [1]. The data are by nature, standardised as the survey is carried out at the same time each year, in the same locations. The length frequency distribution (LFD) from the survey suggest sub-legal adult lobsters are the primary catch, as most of the data related to fish below the legal minimum length of 87 mm carapace length (Figure 7). This could be due to the spatial locations of the survey, although the sites reportedly cover the major commercial fishing grounds (Government of Jersey Pers. Comms,). Another cause of right skewed LFD could be due to the timing of the survey, which may coincide with the major moulting and mating season. Mature lobsters mate whilst the female is soft following moulting. Whether immature lobster follow the same moult timing if they are not mating is not well understood. Length frequency data from across the year from a survey may help understand these patterns more fully.

The survey therefore provides an index of recruitment into the fishery (as most of the catch are undersized). The survey does not provide an index of abundance of adult lobsters within the fishery.

6.2.1 Recommendations for fishery independent catch and effort

Robust fisheries stock assessments require several indices that can be used as proxies for indices of abundance, and recruitment. While an index of abundance can be calculated from the commercial catch and effort data (by standardising the catch rates as catch per unit effort, (CPUE) or landings per unit effort (LPUE)), these indices are inherently biased towards fleet dynamics: manifesting either as fisher behaviour (which can, to an extent be accounted for), or market-driven changes (much harder to account for statistically).

The catch and effort from the independent survey provides valuable information on CPUE for two months of the year and provides an index of recruitment. The independent CPUE does not cover the whole fishing season, with a potentially biased right skewed length-frequency distribution (LFD). Further research into seasonal variation in LFD or spatial representativeness of the survey locations would potentially provide information on how the survey data could be used to generate an index of abundance of adult lobsters.

RECOMMENDATIONS

Investigate more thoroughly the link between the index of recruitment and animals entering the fishery, to understand how the survey catch, and effort can inform fishery assessments.

Research to understand the source of the right skewed LFD from the survey. This could be done through at sea observations of the whole catch LFD across the season at set locations from the commercial fleet and/or specific scientific research surveys to the fixed survey stations across the season.

It would not be advised to alter the timing or location of the current survey as this would impact the continuity of the time series. However, if the location or timing of the survey is implicated in under-representing adult lobsters in the survey then it may be necessary to expand the data collection to include a possibly additional survey that measures all animals from pots caught across the spatial extent of the fishery (using fixed sites), throughout the year.

This could be achieved by:

- A research survey (fully independent)
- Observers on boats to measure a proportion of lobsters per pot, string, and trip
- Potentially contracting the survey to commercial fishers at set time periods during the season.

6.3 Other sources of fishing mortality

A major source of fishing mortality that impacts the Jersey fishery is the Normandy portion of the stock. As the combined Normandy and Jersey Lobster fishery is part of a Unit of Assessment for the Marine Stewardship Council, it is assumed that data are shared between jurisdictions relating to commercial catch and effort so that fishing mortality can be accounted for as accurately as possible within the stock. It is recommended that this continue, and all data are shared and made available to account for total fishing mortality (F) within the Jersey fishery.

Recreational fishing and bycatch are other potential sources of fishing mortality within the lobster fishery to be accounted for in a complete stock assessment. Commercial vessels from Brittany may also catch lobsters in Granville Bay, but these catches are low - the Breton fishery lands only approximately five tonne of lobster per annum. Additionally, there are no Guernsey vessels with licenses to fish within Jersey waters. Bycatch of lobsters from trawlers in the fishery area is also reported to be low[1].

Recreational catches are assumed to be low (2.5 tonnes in 2015, estimated by Fisheries and Marine Resources, Jersey), and Jersey legislation limits recreational fishers a daily bag limit of 5 lobsters per person.

6.3.1 Recommendations for data on other sources of fishing mortality

Robust fisheries stock assessments require an understanding of all sources of fishing mortality. The Jersey lobster fishery has the main source of fishing mortality from the commercial sector, and only approximately 2.5% (2.5 tonnes of ~100 tonnes) are likely to come from recreational fishers. Data are not readily available for bycatch of lobsters from other fisheries.

Although the recreational catch is low, it is likely that recreational fishers enjoy catching lobsters, and have a stake in the health of the future fishery. It is recommended that engagement with recreational fishers allows for a good relationship to develop between the regulator and the fishers. If objectives are developed for the future of the fishery, recreational stakeholders should be included for maximum impact. Some data may be available from pre-existing data sources (Hyder et al., 2018).

RECOMMENDATIONS

Survey the recreational fishery to collect data on catch, effort, fishing location, and biological data (e.g. sex, length, reproductive status. This could be achieved through:

- Phone or internet surveys.
- Development of a recreational fishing app.

Collect data on lobster bycatch in other fisheries.

Continue to enable data sharing between jurisdictions regarding bycatch and fishing mortality across the stock.

This could be achieved through:

- Regular data sharing workshops between fisheries scientists and biologists.
- Regular collaborations to discuss new analyses that will contribute to an enhanced stock assessment for Jersey lobster.

7 Biological data

To inform sustainable management of a fishery, understanding the biology and ecology of the species forms a fundamental part of the fishery management. Life history underpins any stock assessment and can be summarised by the description of how an individual grows, reproduces, and dies. Fisheries stock assessments express life histories of fish by describing individual growth, length-weight relationships (weight-at-length), size (or length) at maturity, fecundity at size, maximum size, and mortality (natural, and fishing induced) [45,49].

If using an integrated stock assessment model, some biological parameters are estimated from other sources of data, however the gold standard would be to have all these parameters well understood for the species that is being fished, in the area they are being fished, using reasonable timeframes for parameters (e.g. describing the current state of the fishery, and understanding how this has changed since fishing began).

The lobster fishery in Jersey has collected data on European lobster biology through fishery independent surveys, commercial landings surveys, and student or researcher-led projects. Gaps in research and key parameters could be collected from work being completed in neighbouring fisheries in the European Union, and the United Kingdom.

In the next sections the fundamental parameters underlying fish population dynamics are outlined, with descriptions of data available for the Jersey lobster fishery, and opportunities for collecting further data, or utilising data from neighbouring lobster fisheries.

7.1 Recruitment

In this context, recruitment is referring to the recruitment of undersized lobsters into the population that is exploited by the fishery. The annual fishery-independent survey (occurred every May and June since 2004 (except 2015 when there was no survey)), uses the same pot types as in the commercial fishery, but without escape gaps, to allow for total abundance per pot to be quantified and to allow for all size classes of lobster to be measured. The lack of escape gaps also allows smaller lobsters to be caught, and retained as they cannot escape from the pots and therefore produces a useful index of recruiting length classes.

The annual fishery currently collects data on the abundance, length frequency, and sex of lobsters (e.g. lobsters) and, due to the good number of small lobsters caught, provides an index of recruitment to the fishery through a calculation of catch per unit effort (CPUE, kg per 100 pot-lifts) annually.

The survey collects length composition data (length-frequency) that could be compared to the commercial fishery at the same time of year, however the commercial fleet uses pots with escape gaps, and as complex behavioural interactions are likely within pot fisheries [50,51], the comparison between the survey and commercial data are imperfect. The survey locations are located of traditional inshore fishing grounds, however some recent expansion into deeper waters by a few boats has shown an increase in larger size classes in the commercial data in recent years, which is not seen in the annual survey (Figure 7). Consideration could be given to understanding this spatial variation in size frequency data and the potential inclusion on new sites in these deeper waters.

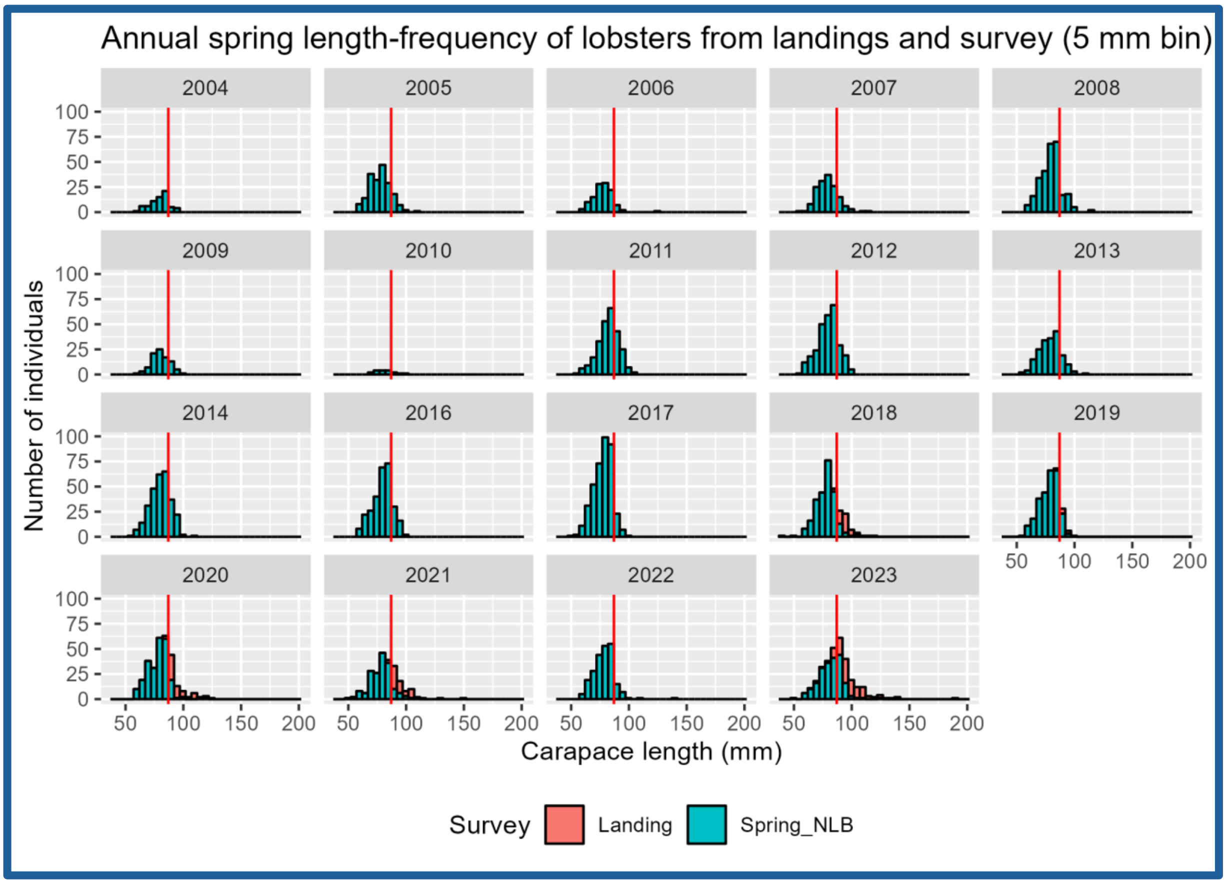

Figure 7: Length frequency information for all animals in the fishery independent survey ('Spring_NLB', blue bars), and the commercial landing data ('Landing', red bars) during the spring months (May and June) across all years. The commercial landings survey started in 2018. Numbers of sampled animals are far higher in the fishery independent survey than the landings survey. The red vertical line marks current legal minimum length (LML = 87 mm).

There is no reliable information on the stock-recruitment relationship. The stock-recruitment relationship is the relationship between the overall spawning biomass, the number of eggs produced, the number of puerulus that settle, and the resulting number of pre-recruits that moult and are recruited into the fishery. This is because lobsters have a pelagic larval phase, that for European lobsters is approximately 10 months before they settle on the substrate and continue moulting into adult lobsters. Currently, Jersey (as with other European lobster fisheries) has little information on where these settlements take place.

7.1.1 Recommendations on recruitment data

Collecting data on recruitment for fisheries is difficult, but even more so for decapod crustaceans. The long pelagic larval phase, coupled with cryptic juvenile stages makes identifying survey areas for pre-recruits difficult to predict. Once these areas are identified, data collection for pre-recruit indices of similar animals (spiny lobsters: Southern Rock Lobster (*Jasus edwardsii*) and Western Rock Lobster (*Panulirus cygnus*)) has required labour-intensive methods to collect pre-recruits on structures underwater, and then have teams of divers or surface collectors to count and record numbers of individuals. Some data are available on recruitment habitats of juvenile American lobster (*Homarus americanus*)[52,53], although similar investigations applied to European lobster were not successful[54].

By occurring at the same time each year, the survey is providing an indicator of individuals that may be available to the fishery in the future. To fully understand how long it takes for the undersized lobsters to be recruited into the fishery, more extensive length data need to be collected from the commercial fishery, including data on undersized lobsters. In the MSC Report for the fishery, they mention a spike in abundance of undersized lobsters in 2017, and predicted these would be seen within the fishery as an increase in catch. This has not materialised (Figure 4). This may be due to heavy fishing pressure on animals as they enter the fishery, which is not being picked up in the landings survey. With a lack of overlap between the survey data, the fishery (landings size-structure data), and no commercial-pot survey, it is hard to draw a conclusion either way.

RECOMMENDATIONS

Due to the lack of understanding of where European lobster larvae settle, it is recommended that data collection relating to recruitment focusses on recruitment of juvenile lobsters into the fishery (e.g. not on larval recruitment).

To continue to understand how juvenile lobsters recruit into the fishery, the survey should be continued at the same time each year as this provides an index of recruitment into the fishery. Additional sites in deeper water sites recently exploited by the commercial fishery would give a fuller length distribution.

A fishery-dependent survey (meshed or closed pots on-board commercial vessels) would provide an index of recruitment into the fishery from across the fleet.

To understand how the numbers of undersized lobsters are recruiting into the fishery, and whether recruitment pulses are translating into increased catches of legal lobsters, survey data from either landings data, commercial vessels, or a fixed site survey, needs to be conducted year round, for several years, with

7.2 Growth and length-weight relationships

Lobster growth is incremental in nature, with growth only occurring at onset of moulting (thereby being the impetus to moult into a larger exoskeleton). Modelling of growth in fisheries stock assessment models has been extensively studied [55–57], and in most integrated models some form of the von Bertalanffy growth model is used [58]. This model is ubiquitous in nature, in animals that show asymptotic growth (e.g. most fin fish). Lobsters do not show asymptotic growth throughout their life, although their growth can, and is, approximated using von Bertalanffy growth models in integrated assessment models, despite this not being the optimal method [59]. Modelling growth in lobsters is necessary for length-based integrated stock assessment models, as they form the basis for the creation of length-transition matrices, or growth-transition matrices within the model (Punt, Haddon and McGarvey, 2016; Cronin-Fine and Punt, 2020; Punt, 2024).

Growth data in lobster fisheries can be collected using data from catch-mark-recapture studies. In lobsters and other crustaceans, animals are caught usually during the research survey, tagged with small T-bar tags into their abdomen, and then released again. Sequential surveys recapture tagged animals, measure them and record changes in growth. Time delays in moulting, linked to the process of capture and tagging are accounted for in growth models, along with measurement error [63].

Where tagging data are not available, a modelled relationship for 'growth' (weight-at-length) can be estimated using length (carapace length, mm) and weight (wet whole animal weight, g) data. The Jersey fishery collects length and weight data from both the independent fishery survey and commercial landings data. These data can be modelled to inform parameters in a simple length-weight relationship:

$$W = a \cdot L^b$$

Where W = weight (g) of the animal, L is the carapace length (mm), and a and b are estimated by fitting a model to the data.

It is important within fisheries modelling and stock assessment to understand whether length-weight relationships are sex-dependent. Accounting for sex differences in biological parameters is important to allow for more accurate estimates of both fishing mortality, natural mortality within a population, and overall biomass estimates, particularly if using integrated modelling approaches. In many species seasonal or spatial closures for one sex (usually females, during spawning) should be accounted for in modelling approaches, and so an understanding of any sex-related differences in growth is important to acknowledge.

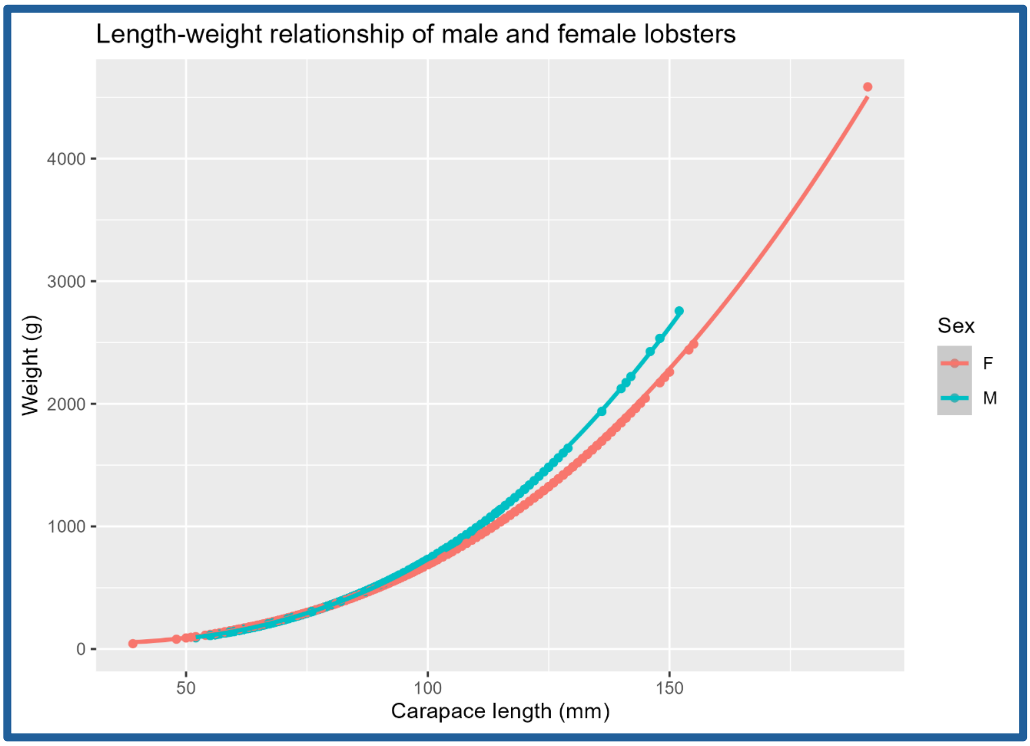

Figure 8: Length (carapace length, mm) to weight (whole animal weight, g) relationship of all measured lobsters in both the spring survey, and commercial landings data in Jersey. Data are aggregated from all years. Data are plotted with a line fitted to the data using the ***fit = 'loess'*** method in **ggplot2** package within **R** (R Core Team, 2024).

Figures 8 and 9 are the male and female carapace length (mm) to whole weight (g) relationships for all data aggregated (fishery independent (survey data), and commercial landings data). Data are aggregated for all years, however annual analyses may be important to consider accounting for potential climate-induced changes to length-weight relationships, especially as other parameters vary geographically [30,31].

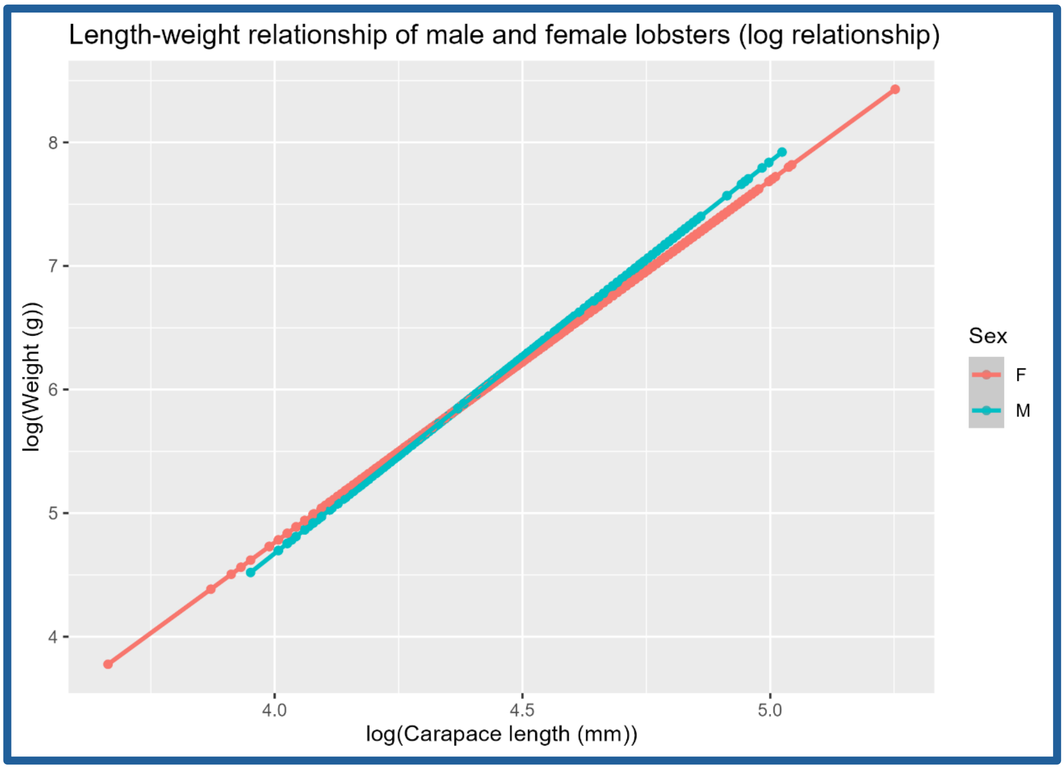

Figure X: Length (log(carapace length), mm) to weight (log(whole animal weight), g) relationship of all measured lobsters in both the spring survey, and commercial landings data in Jersey. Data are aggregated from all years. Data are plotted with a line fitted to the data using the ***fit* = *'lm'*** method in **ggplot2** package within **R** (R Core Team, 2024).

7.2.1 Recommendations on growth and length-weight data

Understanding growth of the fishery species is key to being able to sustainably manage the fishery. European lobsters are likely to display spatially variable growth in the Jersey region, based on studies looking at life history parameters around the UK [31]. It is likely that the Jersey fishery is a small enough spatial area that growth does not vary significantly within the fishery area, however it would be prudent to continue to collect data from all areas of the fishery every year to understand whether there are spatial or temporal differences in growth and/or length-weight relationships. If there are found to be significant differences in the growth of lobsters in different areas of the fishery, this can be accounted for by either averaging growth across the entire region, and acknowledging the potential issues with this (under, or over-estimating growth of individuals); or estimating growth parameters for each biological area separately (which, if differences are significant, may require finer scale stock assessments in general).

Current data collection is not sufficient to have an accurate estimate of spatial differences in growth parameters. It is recommended that power analyses are undertaken to estimate the number of samples required to estimate spatial differences growth parameters, for each sex.

There is no tagging data for the fishery. For accurate growth estimating, including a fishery independent tagging program would improve the understanding of individual growth, timing of moulting, possible biomass estimation (through mark-recapture analyses), and estimates of natural mortality. Tagging programs are expensive, and require stakeholder engagement, and buy-in to provide data back to the fishery, however these sorts of programs can also be used to improve stakeholder relationships with fisheries management.

Collection of length and weight of animals is cheap to facilitate and can be incorporated into commercial daily logbooks. It is recommended that after power analyses to determine the number of samples required to fully understand length-weight and growth relationships throughout the fishery, that fishers are required to measure a particular number of lobsters per pot per vessel (length, weight, sex, reproductive state). These metrics will also feed into previously described parameters (e.g. recruitment, section 4.1; maturity, section 4.3; natural mortality, section 4.5). Length-weight data collection can also occur through more extensive port sampling, or through citizen science programs through recreational data collection.

Length-weight data will also contribute to a greater understanding of other aspects of the fishery (e.g. identification of recruitment pulses or 'cohorts' of undersized lobsters will provide additional information on population dynamics). Length data also is the basic additional data needed for more complex and comprehensive stock assessment methods (e.g. any integrated modelling requires robust length-frequency analyses using at least annual, if not monthly sex-based length-frequency data).

RECOMMENDATIONS

Undertake power analyses to get a robust estimate of length-weight and/or tagging returns data required to fully understand the spatial extent of sex-based length-weight and growth relationships.

Once optimal sample size is understood, aim to collect data from both commercial vessels, commercial landings data, fishery-independent surveys, and citizen science programs on:

- Length (carapace length, mm) and weight of individuals from across the spatial and temporal extent of the fishery (repeated annually)
- Individual growth, through a comprehensive tagging program (will require coordination and buy-in from neighbouring French (and possibly UK) fisheries to return tag data. This will also require recreational fishers to report tags too – something that can be incentivised e.g. tag lottery rewards.

Use and share data from other, neighbouring European lobster fisheries (France, and UK) relating to length-weight relationships, and tagging programs.

7.3 Maturity data

Understanding the size at which lobsters mature, and produce eggs is important to ensure that a proportion of female lobsters are protected for at least one egg production cycle prior to being available to the fishery. This means that the legal minimum size for female lobsters should allow for at least one growth increment to occur after maturation to allow at least one cycle of eggs into the water prior to being caught.

Size at maturity in clawed lobsters can be measured through a variety of approaches, each having slightly different interpretations. Size at onset of maturity has been estimated through both identifying the smallest (carapace length, mm) 'berried' female (a female carrying eggs) observed within a population, and by estimating the inflection point in the carapace length to abdomen width relationship in female lobsters. Size at physiological maturity is estimated through dissection of lobsters to stage their ovary development. Whilst lobsters may have mature ovaries, there is evidence to suggest that successful mating and fertilization may not always occur at the initial onset of maturity in smaller females. Therefore, a measure of functional maturity that observes the proportion of females with eggs on their abdomen is a more accurate estimate for size at maturity for a population. These observations need to occur in winter months as this is when female lobsters incubate their eggs, and an accurate estimation can be made. At other times of the year, you may only have a small proportion of females carrying eggs, even at very large size classes. However, it is likely that in older, mature females there are some animals that don't reproduce annually, and the upper asymptote may not reach 100% mature. Therefore, a 3-parameter logistic regression needs to be implemented that allows the upper asymptote to vary whilst fixing the lower asymptote to zero.

A new study has also shown that the rapid widening of the abdomen at puberty takes place over approximately 2 moults before the growth pattern returns to isometric growth (Hold et al., *in prep*). This results in multiple inflection points associated with these pubertal moults with size at onset of maturity for females estimated at 70.5 mm (variation: 69.1 to 71.9 mm) and size at physiological maturity for females estimated at 89.6 mm (variation: 87.6 to 91.7 mm) (Hold et al., *in prep*).

In Jersey there are no data from dissections on physiological maturity and observations on berried females has not occurred during winter months within the fishery independent survey. The fishery independent survey has been timed to occur in the spring months, and has targeted smaller individuals, therefore although data have been collected on whether females are berried or not, data are insufficient to provide reasonable estimates on size at maturity (Figure 10). Similarly, data from landings on berried or unberried females are low in numbers (Figure 11).

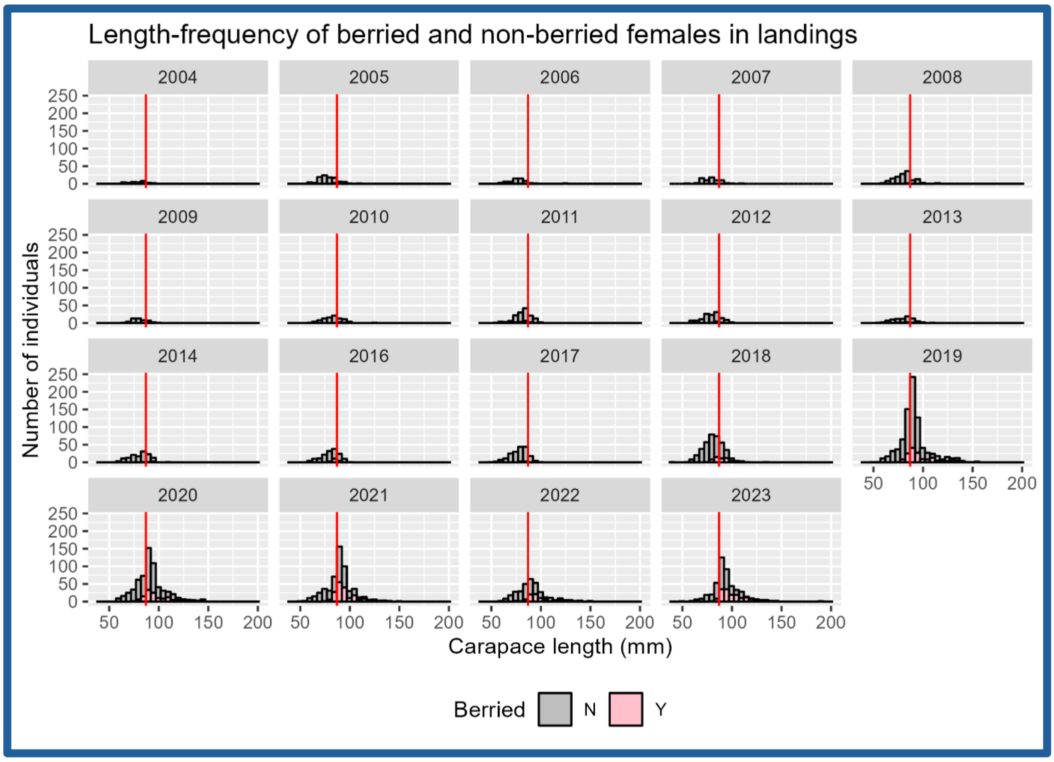

Figure 10: Length-frequency of berried (pink) and non-berried (grey) females within the landings data. Data are aggregated across all months and show a general lack of data to make accurate estimates of size at maturity. Red vertical bars signify current legal minimum length for both males and females, at 87 mm carapace length.

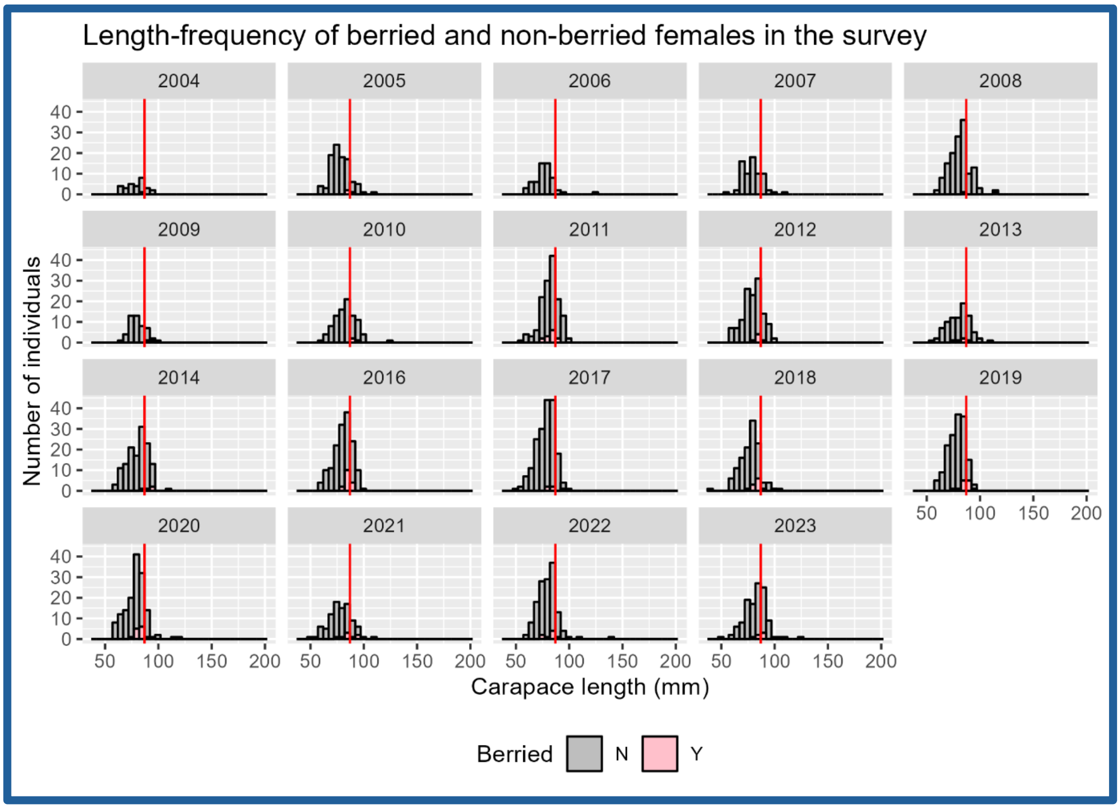

Figure 11: Length-frequency of berried (pink) and non-berried (grey) females within the spring fishery independent data. Data are aggregated across all months (mainly May and June each year) and show a general lack of data to make accurate estimates of size at maturity. Red vertical bars signify current legal minimum length for both males and females, at 87 mm carapace length.

Data on carapace length (mm) and abdomen width (mm) in males and females has been collected in both the commercial landings data and fishery independent data and could be used as a proxy for the onset of maturity in females. However, the spatial and temporal extent, and sample size is the same as that for the length-weight relationship, and the same restrictions on data quality apply as in the previous section.

Size-at-maturity data are important to quantify within population dynamics modelling frameworks, as this determines the biomass of the population that are contributing to the next year's population (in combination with the length-frequency data).

Relatively good estimates of size at maturity are critical to have if the fishery is to be sustainable in the long term. In crustacean fisheries, it is important to protect the female spawning biomass so that at least one spawning cycle can occur before females are recruited into the fishery. One way to control for this within fishery harvest control rules, and management frameworks, is to ensure that (within bounds of certainty) the legal minimum length for female lobsters is at least one size class (or growth increment) above that of the size of maturity to allow animals to reproduce before they are caught.

7.3.1 Recommendations for maturity data

Size-at-maturity (either carapace length, or abdomen width, or a combination of both) is important to understand within the Jersey lobster fishery. It is highly likely that size-at-maturity varies with climatic conditions, such as water temperature [30]. Data need to be collected annually, during the winter months, from data sources that cover the spatial extent of the fishery. Data can be collected either from a fishery independent survey, or from the commercial fleet (through on-board data collection in daily logbooks e.g. [64]), or through landings data (as there are currently no restrictions on retaining or landing berried females).

Appropriate sustainable fishery management would be based on the size-at-maturity of females, to allow for individuals to complete at least one spawning cycle before being vulnerable to the fishery. The long brood-time for lobsters makes them vulnerable to fishing for over 9 months whilst carrying eggs. with the current MLS approximately equal or greater than size at physiological maturity this means lobsters are vulnerable to fishing during the carrying of their first brood and may not spawn before being caught. Monitoring size-at-maturity to ensure that the legal minimum length of female lobsters is at least one growth increment greater than the legal minimum length in the Jersey fishery is critical for sustainable fishery management.

RECOMMENDATIONS

Undertake data collection for size at maturity during the winter months. This could be completed annually (if long-term data are required – e.g. to understand the impact of, for example, climate change on lobster maturation), or in a one-off winter research survey targeting female lobsters.

Ensure consistent data on female berried state is included in on-board commercial data collection (fishery-dependent survey data), and in further fishery independent surveys (even if during spring – it is important to understand changes to timing of spawning).

Undertake monitoring of size-at-maturity in relation to legal minimum size.

Use and share data from other, neighbouring European lobster fisheries (France, and UK) relating to size-at-maturity.

Consider increases to the minimum landing size to protect egg-bearing females, and to ensure sufficient females are able to spawn before being selected by the fishery.

7.4 Fecundity

Fecundity in egg-bearing lobsters refers to the number of eggs that a female can produce, and the quality of those eggs. The number and quality of eggs are directly related to an individual's fecundity. Understanding the relative proportion of fecund females in a population then gives an estimate for the population's egg production potential. European lobsters show spatial variation in fecundity throughout their range, however in the spatial context of the Jersey fishery, the lobsters could be assumed to have similar egg-bearing potential [15,64]

In lobster fisheries, to get an estimate for the population's fecundity or spawning potential, you need to have information on the length-frequency distribution of female lobsters, in a timeframe that is relevant to the spawning time of the population (e.g. you need to have length-frequency data from mature females in the spawning season over several seasons).

The Jersey fishery has some data on the length-frequency of mature females, that has been described in the previous sections. There have also been some student projects looking into the number of eggs that individual females carry. In spiny lobster fisheries, a simple relationship is used to estimate size-based fecundity, based on the carapace length, and the likelihood an animal is mature (which in turn is based on size-at-maturity).

Fecundity is an important parameter in size-based integrated stock assessment models, however currently it is not necessary for either the Jersey lobster fishery harvest strategy, or harvest control rules.

7.4.1 Recommendations for fecundity data

The harvest strategy and harvest control rules for the Jersey fishery under the MSC certification do not contain any data relating to fecundity related parameters (e.g. egg production levels). However, if the Jersey portion of the fishery decides to use an integrated stock assessment model that requires data on fecundity, it is recommended that data on size at maturity (section 4.3), and length-frequency (section 5 – survey data) are robust.

Investigating egg numbers in berried females of different size classes would also be needed to understand the potential number of eggs that females carry at a particular carapace length. Then a simple relationship can be used to describe fecundity per length class (if using a length-based stock assessment model).

RECOMMENDATIONS

If egg production data are needed for a future harvest control rule, collect data that can be used to estimate length-based fecundity or egg production. This could be completed by either:

- Using and sharing data from other, neighbouring European lobster fisheries (France, and UK) relating to length-based fecundity estimates, if figures exist.

Using data from published literature or supporting research programs into the fecundity of European lobsters.

7.5 Natural mortality

Natural mortality within fishery stock assessments is complex, and often poorly estimated. For a recent review, see [65]. Natural mortality is a key parameter in most integrated stock assessment models, and often can have a significant impact on estimated outputs from models [66].

Natural mortality can be estimated from tagging programs in lobsters, however significant data are required over several years, especially in a long-lived species such as the European lobster. Due to the expensive nature of tagging programs, even fisheries with extensive time series in survey data, either fix natural mortality in a model, or use estimates from similar species, and fix the parameter.

Currently the Jersey fishery does not have an integrated modelling framework for the fishery, and the harvest strategy, and harvest control rules do not require outputs from a quantitative model that would require an estimate of natural mortality. If the stock assessment moves towards a modelling framework requiring an estimate of natural mortality, this could be taken from a stock assessment of a neighbouring fishery of European lobster, or from similar lobster species, and sensitivity analyses or scenarios provided using estimates of natural mortality.

7.5.1 Recommendations for natural mortality estimates

Currently the Jersey lobster fishery does not require an estimate for natural mortality. As this is a difficult parameter to estimate, it is recommended that if a tagging program is established, that estimates of natural mortality are derived from that, or from estimates from neighbouring fisheries, published literature, or research studies.

RECOMMENDATIONS

If integrated stock assessment models are implemented within the fishery, collect data that can be used to estimate natural mortality. This could be completed by either:

- Using and sharing data from other, neighbouring European lobster fisheries (France, and UK) relating to natural mortality estimates, if figures exist.
- Using data from published literature, or supporting research programs into the natural mortality of European lobsters.

If a tagging program is instigated, and natural mortality data are needed for integrated stock assessment models, use multi-year data to estimate natural mortality.

8 Surveys

Most of the information on data collected from surveys has been covered in sections 3 and 4 relating to commercial data collection and biological data collection. The next two sections will cover a brief outline of the data collected in both fishery-dependent, and fishery-independent surveys for the Jersey lobster fishery.

8.1 Fishery-dependent surveys

Currently, no biological data are collected from vessels in a fishery-dependent survey. In many trap-or pot-based fisheries, fishery-dependent biological data are collected from commercial vessels to provide an additional source of data to inform both biomass and recruitment indices. Some fishery-dependent surveys in lobster fisheries require fishers to report data from a certain number of pots per trip or per day, others require fishers to report all data from additional pots that generally have escape gaps closed or removed, and/or are meshed to capture a wide range of animal sizes. Fishers are required to report lengths, sex, and reproductive state (e.g. berried, not berried). These data are then used in length-frequency analyses, and general biological analyses, and allow for data collection across the entire spatial and temporal distribution of a fishery.

There are biological data from commercial landings – e.g. length, sex, and berried state of females, however the lack of spatial information from the landings data (e.g. the exact location of the catch, as opposed to where the fish were landed), and detailed temporal data (e.g. the day the fish were caught), make detailed biological analyses more difficult to undertake. If independent data validation or collection methods are available, this could be one way of collecting these data from the fishery (e.g. on-board cameras).

The lack of standardisation for the landings data (e.g. a set number of individuals measured per month, per landing site) make it difficult to understand how representative the landings data are of the entire fleet's catch. Understanding the proportion of animals measured within landings data are critical to accurately estimating important life history parameters such as weight-at-length for the population (as opposed to the individual).

8.2 Fishery independent surveys

The fishery independent survey takes place at fixed stations that are fished every year. The fishing gear consists of three strings of ten 28-inch Parlour pots, constructed without escape gaps, set at 20m intervals on a 2m strop off a backline with belcher buoy and then terminated on the surface marked by buff or kinghead. The pots are D shaped and match those used by the industry at present. The pot is weighted through their metal structure and are closed with a hook on a rubber strop. Each pot is baited with one horse mackerel (*Trachurus trachurus*) and one red gurnard (*Aspitrigla cuculus*) every fishing day with old bait removed. Pots are left to soak for 48 hours at a time.

On hauling the pots, all lobsters are sexed and measured for the following data:

- Sex

- Carapace length (mm)
- 2nd abdomen segment width (mm)
- Crusher (large claw) length (mm) – measured from joint with 'elbow' to fixed tip
- Crusher width (mm)
- Crusher depth (mm)
- Missing or damaged appendages noted
- Any small appendages noted (normally regrowth post-dropping a limb)
- Telson condition
- Shell condition
- Presence and development stage of eggs

Additionally, data from bycaught chancer and spider crabs are collected:

- Length, width, and depth (mm) of carapace
- Abdomen width (mm)

All other crustaceans caught in the pots will be recorded, with numbers and condition recorded for crab species.

8.3 Recommendations for survey data collection

The Jersey lobster fishery survey data should support the aims of the harvest strategy, and harvest control rules for the fishery. Currently the harvest control rules, and strategy are set up for the MSC Certified fleet which includes the Normandy portion of the stock. There is one main issue to address before identifying aims for survey data collection in the fishery. This is:

1) Whether the stock assessment for the Jersey lobster fishery will be completed at a stock level or independently by Normandy and Jersey fisheries. This will help to understand whether fishery-dependent data can be collected by just Jersey-based vessels, or across the entire Normandy and Jersey stock.

Once the spatial scope of the stock assessment is defined, then the harvest control rules need to be defined, which requires objectives to be determined for all stakeholders in the fishery (e.g. what are the aims of fishery management for the Jersey lobster fishery?). Determining the objectives for the fishery will allow for suitable harvest control rules to be defined. Once these are determined, it will be easier to understand what type of stock assessment would be the most appropriate for the fishery, based on the current data collected, and the data required to manage the fishery using the harvest control rules.

The current harvest control rules for the Normandy and Jersey fishery rely on two indices – the standardised index of abundance (LPUE) for the fishery, and a measure of current CPUE or LPUE [1]. Current data collection from both the fishery-dependent and fishery-independent surveys are sufficient to meet data requirements for the reference points within the harvest control rules.

If the Jersey fishery moves towards a harvest strategy and harvest control rules that has target and limit reference points relating to estimated biomass (spawning, or total biomass) and egg production, estimates will need to come from a modelling framework. Data collection relating to biological variables such as length-frequency of the population, sex-dependent variables such as fecundity, growth, and potentially catchability or selectivity, will need to be collected from both fishery-dependent (e.g. from commercial vessels) and fishery-independent sources.

9 Stock assessment review and recommendations

As outlined previously in this report (section 4: Current Stock Assessment Approach), the Jersey lobster fishery is currently assessed using a weight-of-evidence approach. The Jersey portion of the stock is also assessed as part of the Normandy and Jersey Lobster Fishery MSC Unit of Assessment, using separate data analyses.

There has been a recent peer review of the stock assessment that was completed for the MSC Certification [46]. It must be noted that the peer review is not entirely independent, as the same author has been involved in the assessment of the fishery for several years [2].

Notwithstanding this, the stock assessment review suggested that a 'fully documented benchmark stock assessment' is a necessary next step to direct future developments of the harvest strategy for the whole stock. It is assumed that they are referring to a stock assessment modelling framework, as opposed to a stock assessment in the broader sense.

The report also suggests that the models that have already been trialled be continued, with full documentation of the details relating to data treatment and sensitivity of key model outputs (e.g. relative biomass (B_0 / B_{MSY})).

Although data-limited modelling options should be investigated for the Jersey fishery, length-based modelling approaches could also be investigated with a focus on modern methods and frameworks that have been used within other crustacean fisheries that provide flexibility, speed of processing, and bespoke crustacean-based methods [62,67–69]. These crustacean-specific modelling frameworks utilise data sources that the fishery has already started collecting, and data sources that are not currently used within either a weight-of-evidence approach, or within the joint stock assessment (e.g. length-frequency data, berried female data).

The modelling frameworks that have been trialled on this stock (C-MSY, SpiCT and JABBA) are data-poor and data moderate methods initially developed for fin fish based on surplus production and biomass dynamics models. These models are simple, which is both a strength and a weakness. Few data are required (time-series of catch, and an abundance index – in this case the IAS, and standardised LPUE for the joint fishery). These models can evaluate management actions; however, they do not account for the population dynamics (e.g. growth, mortality, stock-recruitment relationship), or size- or sex-specific issues (e.g. selectivity changes, discarding practices) [70].

Catch-MSY based methods are useful when the objective of the fishery is to attain maximum sustainable yield (MSY). MSY is the maximum yield a stock can sustain for an indefinite period, under constant environmental variables, and harvesting at MSY results in the maximum growth rate of the population. Estimating the biomass necessary to sustain MSY (B_{MSY}) requires a robust understanding or estimate of the virgin biomass (B_0) carrying capacity (k), the resilience (r) of the stock (the maximum intrinsic rate of population increase), and a time-series of catch from the population e.g. [71] , although there are many current parameterisations of Catch-MSY available.

The current Catch-MSY models used in the Normandy and Jersey fishery contain data from 2007 onwards. The modelling of Catch-MSY assumes the fishery was at carrying capacity in 2007, however this may need re-visiting, considering the long period that people have fished the waters surrounding the Channel Islands, and the coastal areas of France and the United Kingdom, both of which are relatively easy to access from Jersey waters

The standardisation methods for the Jersey portion of the stock were unavailable for this review. It has been noted that catch cannot be linked to specific pot type, and so a first recommendation would be to spend some time assessing data and assigning catch to pot type based on vessel, skipper, and general fishing practice information (this could be collected via interviews with fishers regarding their fishing practices).

Generalised linear mixed models (GLMMs) are good candidates for catch (or landing) rate standardisations, and all suitable variables, or factors affecting landed catch, should be included in the standardisation process. This could include, for example, spatial and temporal variables, temperature, and depth data, as all are likely to influence stock abundance, and therefore, catch of lobsters. The first step in this process would be to review the methods (when available) used in the current LPUE standardisation process, and the index of abundance (IAS) for the joint MSC fishery. Care needs to be taken when assessing whether the reference fleet (or reference data from 2007) is appropriate for the LPUE to be standardised against, or whether the index could be standardised to the mean LPUE over time. These decisions should be made in the context of harvest control rules.

Outputs from the standardisation of LPUE need to have uncertainty quantified (e.g. confidence intervals) to allow for stock status to be expressed within a probabilistic framework. Additionally, calibration or comparison of raw LPUE to standardised LPUE is important to quantify to allow for additional variables that are hard to quantify to be visualised (e.g. effort creep, or technological advances in fishing vessels over time). A review of the standardised LPUE would be a good first step, and there are many resources available to help (see (Hoyle et al., 2024)). The standardised LPUE can continue to be used within the weight of evidence approach but can also be one of the inputs into an integrated modelling framework in the future.

9.1 General stock assessment recommendations

Current understanding of the stock structure of European lobster in Jersey waters suggest that the Normandy and Jersey fisheries likely represent an assessable unit. Therefore, continued on-going scientific collaboration between Normandy and Jersey is critical to ensure data collection and data analyses are relevant to the entire stock.

Firstly, a joint harvest strategy framework should be developed or re-assessed, between the two fisheries. This could include a review of the current harvest strategy, and harvest control rules. This review would then provide relevant control rules that each jurisdiction needs to meet, and in turn, data collection requirements into the future.

From this harvest strategy, a Jersey-specific component can then be developed (or independently if the joint assessment is challenging to implement). Within the Jersey-specific harvest strategy, harvest control rules relevant to the spatial extent of the Jersey-specific harvest can then be developed. If these are to include a standardised LPUE reference point, this should be standardised as discussed above.

If a weight-of-evidence approach is continued in the short-term, yearly assessments of length-frequency data for both male and female lobsters, based on the fishery-independent survey, and commercial landings data, should be included within the assessment. Publication of length-frequency distributions from the survey is important for stakeholder engagement and may encourage fisher participation in a fishery-dependent survey, which would improve representative data collection in the fishery.

Publication and sharing of methods relating to the standardisation process of the LPUE and/or IAS for both Normandy and Jersey are necessary for both portions of the stock. For the Jersey fishery, the data need to be allocated to pot type more accurately, which may require a detailed research project to allocate older data appropriately. This will allow a greater understanding of what each fishery's index of abundance relates to, and accounts for, and will allow for more direct understanding of the comparison in LPUE and IAS between fisheries.

Long term time series of data are important in a fishery where the species is relatively long-lived. Therefore, a detailed investigation of Jersey commercial data prior to 2007 is important to be able to have reasonable estimates of fishing mortality over a longer period. Mortality estimates also need to include the recreational component of the fishery and estimates of whether this sector is likely to increase in size and power.

Additional data collection programs that would provide good quality data into a stock assessment modelling framework should be investigated. These include a tagging program (ideally, in collaboration with the Normandy portion of the stock) and utilise other novel techniques to understand size structure within the fishery (e.g. on-board cameras to collect length-based data; Baited Remote Underwater Visual Survey (BRUVs) to identify size structure of populations), noting potential costs, and biases associated with these methods.

Understanding the selectivity of pots and catchability of lobsters throughout a fishing season will be important in the future. There has been some initial data collection within the fishery relating to the efficiency and catchability of different pot types[73], and this work should be built upon to gain a more complete understanding of lobsters and their interaction with fishing gear (Heney *et al* in review). Alternatively, if an integrated model is used, selectivity can be estimated within the model as selectivity is based on the size structure of the animals the pots have collected, thereby accounting for the likelihood that a lobster will enter a pot (catchability)[49].

As a gold standard, stock assessment methods should focus on development of an integrated length-based modelling framework that is specific to crustaceans, is well-documented, and can be applied and tested by several scientists. Regular peer review of data inputs into the stock assessment is required, and methods should be fully reproducible using, for example, git (GitHub) and R Markdown (or similar). A summary of recent efforts in stock assessment modelling in similar species, spiny lobsters, outlines several models that are worth investigating [62], and a recent publication on good practices within stock assessments is also a useful tool for the next stages of stock assessment for the Jersey lobster fishery [45].

RECOMMENDATIONS

1) Comprehensive review of current data analyses (IAS, standardised LPUE) by accessing the methods, and data used in these analyses.
2) Review of initial SpiCT and JABBA models, including the data inputs, assumptions, and parameterisation of the models.
3) Exploratory spatial assessment of the fishery including extent and magnitude of fishing effort over time, and fishery survey locations relative to the fishery.
4) Management Strategy Evaluation of the current Harvest Control Rules to understand the potential impact of switching assessment methods.
5) Clearly defined management objectives for the fishery, including any potential trade-offs, to help outline any changes to trigger, limit, and target reference points. If these are to change from the current trigger, limit, and reference points, then the units will help drive development of an appropriate stock assessment model (that provides those estimates – e.g. biomass or egg production, rather than standardised LPUE that does not require integrated modelling approaches).

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