Fisheries and Oceans Canada | Pêches et Océans Canada
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Pacific Region

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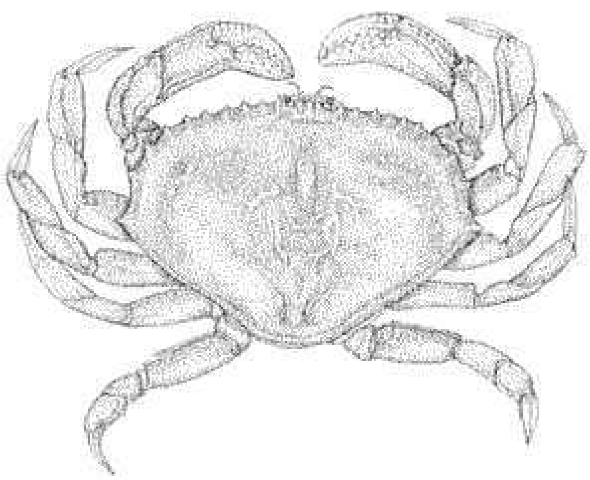
Science Advisory Report 2026/003

STOCK STRUCTURE OF DUNGENESS CRAB (*METACARCINUS MAGISTER*) IN BRITISH COLUMBIA



Dungeness Crab (Metacarcinus magister). Photo: DFO.

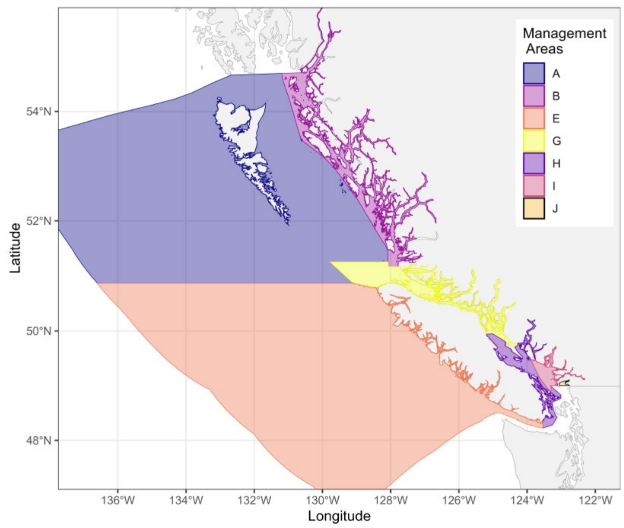


Figure 1. Map of British Columbia showing Crab Management Areas (CMAs).

CONTEXT

Stock Structure of Dungeness Crab (Metacarcinus magister) in British Columbia has been in existence for over 100 years. Fisheries and Oceans Canada (DFO) manages the crab fishery which consists of 7 Crab Management Areas (CMAs; A, B, E, G, H, I, and J) in BC. Dungeness Crab fisheries are primarily managed based on a '3 S' (size, sex, and season) management strategy. To ensure that Dungeness Crab complies with the Fish Stock Provisions of the Fisheries Act, and DFO's Precautionary Approach (DFO 2009), DFO must estimate reference points and stock status. Before this can be achieved, the stock structure of Dungeness Crab in BC needs to be defined. Understanding the biological scale of the stock is important to avoid biased assessments and potentially localized depletions.

Fisheries and Oceans Canada (DFO) Fisheries Management Branch has requested an evaluation of the stock definition for Dungeness Crab in British Columbia from the Science Branch.

This Science Advisory Report is from March 11-13, 2025 regional peer review on the Stock Structure of Dungeness Crab (*Metacarcinus magister*) in British Columbia. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- To meet the requirements of the Fish Stock Provisions under the *Fisheries Act*, the Dungeness Crab fishery in British Columbia (BC) requires a stock definition in order to determine the scale at which reference points should be estimated.
- A template used to delineate Alaskan groundfish and crab stocks was followed to evaluate Dungeness Crab biological stock structure in BC, which included literature reviews of genetic, movement, and oceanographic information, analyses of fisheries data, and a review and new analysis of phenotypic variation.
- Available genetics information, which was spatially and temporally limited, suggested genetic connectivity of Dungeness crab through BC, with some evidence of genetic structure in some fjords.
- Analysis of Dungeness Crab catch per unit effort trends in the commercial fishery did not show differences among Crab Management Areas nor between Pacific Fishery Management Areas.
- Existing oceanographic classifications were reviewed and were found to vary in BC, but shared a common split at the northern end of Vancouver Island where the California Current and the Alaska Current diverge. This break may result in limited larval exchange between northern and southern BC. However, there is a lack of information on larval dispersal to assess this split.
- Analyses of phenotypic traits showed some variability across BC, likely due to temperature differences. Growth is associated with latitude and softshell timing occurs later in the year in offshore and northern areas. Additionally, frequency of egg extrusion differs between California and Alaska.
- Most published work indicates limited movement of adult Dungeness crab, with some exceptions. There is potential for widespread larval movement, which is strongly influenced by multiple processes including biological, geographic, and oceanographic factors.
- Overall, there is evidence of spatial heterogeneity in Dungeness Crab, but there is insufficient information to delineate multiple stocks at this time. However, data are limited spatially and temporally, which leads to uncertainty about the lack of multiple stocks, most notably in fjords where uncertainty is particularly high.
- At this time, it is recommended that Dungeness Crab in BC be defined as one stock.
- Additional information on genetic differentiation and connectivity (e.g., from biophysical models, tagging studies) is critical for understanding stock structure over space and time.
- It is recommended that future work incorporate simulation testing to evaluate/examine the impact of uncertainty in stock structure.
- Fishery management can occur at finer scales than the scale at which a biological stock is defined. Broad biological stock definitions do not preclude finer scale management or assessment.
- It is recommended that the stock definition be revisited as new information becomes available.

INTRODUCTION

Dungeness Crab (*Metacarcinus magister*) is a decapod crustacean found on soft bottom types throughout the west coast of North America from Mexico to Alaska at depths ranging from the intertidal to 230 m (Rasmuson 2013). They are targeted by multiple fisheries throughout their range and have high economic, ecological, and cultural importance in British Columbia (BC).

The Dungeness Crab fishery in BC requires limit reference points (LRPs) in order to be compliant with the newly implemented Fish Stocks provisions (FSP) (DFO 2021). A LRP is the level of abundance or biomass (or an index of these) below which productivity is sufficiently impaired to cause serious harm (DFO 2009). The FSP include requirements to develop and avoid stocks falling below their LRP and to implement rebuilding plans for stocks that fall below the LRP (DFO 2009, 2021; Marentette et al. 2021).

A framework for estimating reference points for Dungeness Crab in BC does not exist due to the lack of an existing stock assessment framework, and the biological stock structure has not been assessed. It is necessary to delineate stocks that are representative of the underlying population structure in order to mitigate against biased assessments and risk of localized depletions (Ying et al. 2011; Berger et al. 2020). The first step of the process to prescribe Dungeness Crab under the FSP is to assess the biological stock structure of Dungeness Crab in BC and to determine if there are multiple stocks that would require separate LRPs.

Stocks can be defined based on both biological and management criteria under the FSP (DFO2021), but mismatches between biological populations (i.e., 'true' stock structure) and management scales (e.g., LRPs) increase the risk of biased assessments, local depletion, and underutilization (Ying et al. 2011; Berger et al. 2020). In the Precautionary Approach framework, a biological stock is defined as "a population of a given species that forms a reproductive unit` with little or no spawning with other units, possessing shared homogenous traits such as occupying the same spatial distribution" (DFO 2021). Many fish stocks worldwide are mismatched with the biological population structure (Reiss et al. 2009). In Canada many stocks are defined based on historical boundaries, due to the lack of sufficient biological information with which to define the stock (i.e., genetics, movement, etc.). It is best practice to define stock boundaries as the most plausible population structure, and multiple possible population structure hypotheses can be compared via simulation testing (Cadrin et al. 2023).

The commercial Dungeness Crab fishery is currently managed with seven Crab Management Areas (CMAs, Figure 1), but these areas may not represent the underlying Dungeness Crab population structure. Aulthouse et al. (2023) estimated reference points for CMAs I and J, but these two CMAs only cover a small portion of the crab distribution in BC. Each of the seven CMAs (Figure 1) has unique seasons and trap allocations (DFO 2024). All areas are passively managed through size limits, non-retention of females, and seasonal effort restrictions such as commercial closures and haul limits. Effort is restricted during the male soft-shell period, to reduce handling mortality of soft-shelled crab. The CMAs are not biologically-based, and the degree of population connectivity between CMAs is uncertain. We aim to identify similarities between CMAs using a stock delineation framework developed in Alaska (Spencer et al. 2010) to assess the biological stock structure of Dungeness Crab in BC.

ASSESSMENT

In Canada, no consistent framework exists for summarizing the available information to define a stock structure, although sections on stock structure have been included in some Pacific groundfish assessments (e.g., Starr and Haigh (2022)). We follow a template used for King Crab and groundfish assessment in Alaska (e.g., Foy et al. 2014, Spencer et al. 2010), taking a comprehensive approach to defining the Dungeness Crab stock by incorporating information on population genetics, harvest trends, life history, movement, and phenotypic characteristics. The approach for assessing each characteristic and the respective results are described below and summarized in Table 1.

Genetics

Approach and Summary

A literature review was conducted to understand Dungeness Crab genetics. This review summarised research conducted in BC, Washington, Oregon, and California. The available information suggests there is a ample genetic connectivity throughout the BC coast. The very limited research in inlets and fjords found a genetically differentiated population in Alison Sound, a long, shallow inlet in the Central Coast (Beacham et al. 2008). A genetically distinct population was similarly identified in the Hood Canal (Puget Sound, Washington) (Jackson and O'Malley 2017), which is another long narrow inlet with limited water exchange. Additional research is needed to understand whether this structure is unique to these areas or characteristic of BC fjord and inlet populations.

Harvest, Trends, and Fishing Mortality

Approach

Fishery information such as exploitation rates, catch per unit effort (CPUE) trends, and fishing distribution were used to infer biological characteristics about the Dungeness Crab stock, and to qualitatively assess risk. Areas with high exploitation rates and highly concentrated fishing effort may be at greater risk of overexploitation. Similar trends in CPUE between areas can be used to identify areas with similar recruitment, mortality, or life history. These similar life histories may be indicative of stock structure.

Spatial concentration of fishing was assessed by plotting all trap hauls from 2000-2023 at the PFMA subarea level. Exploitation rates were summarised for different areas based on previously conducted analyses and research. Trends in CPUE were estimated by first generating a standardized index of commercial CPUE. Commercial CPUE from logbook data was used as there is no consistent survey across the coast. The CPUE was standardized using a generalized linear model to account for changes in fishing behaviour. This model included covariates for year, month, depth, soak time, bait, subarea, and vessel. The standardized index was taken as the year effects from the model and the standard error of year effect coefficients was taken to describe the uncertainty around the index.

A clustering method (Cope and Punt 2009) was used to determine similarities in the time series of CPUE between areas. In this approach, 1000 time series were generated for each area based on the estimated index and its standard error, followed by hierarchical clustering with dynamic time warping (DTW) (Sarda-Espinosa 2024) to identify areas that clustered together across the 1000 iterations. A final hierarchical clustering step was performed on the 1000 cluster assignments to determine the final cluster assignments, and silhouette scores determined the optimal cluster size and goodness-of-fit. As a sensitivity analysis, this method was repeated at the scale of the PFMA subarea to try to identify trends at a smaller scale that were not constrained by the existing CMAs.

Results and Discussion

Fishing effort was found to be highly concentrated around human population centers. Exploitation rates were generally estimated to be high. Exploitation rates were highest in the south (CMAs I, J, and E), where they were over 0.9. Exploitation rates in CMAs A and B were around 0.3-0.7. Exploitation rate estimates for CMAs G and H were not available.

Although the cluster analysis of CPUE data suggested two clusters, the silhouette score metrics from the cluster analysis indicated no evidence to delineate stocks. The sensitivity analysis likewise had low silhouette scores, suggesting there is no evidence with which to delineate stocks.

Behavior and Movement

Approach

Movement of individuals is a key mechanism of gene flow and population connectivity. Movement of adult Dungeness Crab is primarily studied through tagging studies, whereas larval movement can be studied with light traps or fine mesh trawls. This larval abundance can then be analysed for spatial patterns, regressed against environmental variables, or used in biophysical models. In this section, existing literature was reviewed that pertained to Dungeness Crab spawning site fidelity, adult movement, and larval movement.

Results and Discussion

Research in Alaska suggests that Dungeness Crabs show fidelity to the same brooding sites (sites where females carry eggs and bury in the sediment) (Stone and O'Clair 2001). Research on adult movement suggests that large scale movements of adults (e.g., over 100 km) are rare, but some crabs do undergo large scale movements (e.g., 300 km). Research on larval movement suggests that Dungeness Crab have the potential to disperse over large distances due to their 4-5 month larval duration. However, this movement can be disrupted by environmental and physical barriers, such as wind and complex bathymetry. Biophysical models in the California Current indicate that the phase of the Pacific Decadal Oscillation can impact recruitment and that some areas may rely on self-recruitment more than was previously thought (Rasmuson et al. 2022). This indicates most connectivity likely occurs during the larval stage, although further research is necessary to understand the degree of this connectivity.

Barriers and Phenotypic Characteristics

Physical Limitations

Approach and Summary

To understand physical barriers to connectivity that may exist in Dungeness Crab, the authors reviewed large scale oceanographic conditions that have been summarized in ocean classification systems. The oceanographic conditions can impact larval dispersal via ocean currents, and can impact life history through variability in temperature and nutrient availability. Most ocean classification systems divide the BC coast with a north/south split at the northern end of Vancouver Island. Some ocean classification systems also classify the Strait of Georgia separately.

Growth Differences

Approach and Summary

Attempts to estimate Dungeness Crab growth parameters from the length frequency data were unsuccessful; specifically, the length distributions lacked clear breaks or peaks that could be used to indicate age classes. The authors subsequently conducted a literature review. Growth across life stages in Dungeness Crab is variable throughout the range. Growth is typically faster at higher temperatures, such as in shallow bays or lower latitudes (Wainwright and Armstrong 1993). Different growth rates have been observed in megalopae between the Strait of Georgia and outer coast (Cook et al. 2024), which may be driven by genetics and/or temperature. temperature.

Age/Size Structure

Approach and Summary

Size structure was analyzed through space using multivariate regression trees fit to the commercial catch sampling data (based on Lennert-Cody et al. 2010). Commercial data is the most consistent form of size data available. The analysis focused on male crabs, as female crabs are not targeted in the fishery. The predictor variable in the regression tree was the spatial coordinates, and the proportion of crabs in each size bin was the response variable. Regression trees were fit for all years separately as well as all years combined. Goodness of fit was determined with cross validation error.

There was no consistent pattern in the location of the splits (in longitude and latitude) between years. There was a high degree of variability in the number of splits, ranging from 1-7. Because the cross validation error indicated that the model fits were poor, no spatial differences in size structure can be concluded. Further, any differences in size structure may be driven by fishing pressure, raising uncertainty in the applicability of this approach for stock delineation.

Moult Timing Differences

Approach and Summary

We estimated peak male moult timing using previously established methods (Waddell et al. 2016) by determining the time of year in each CMA at which the proportion of soft male crabs was the highest. This was done with both fishery independent and dependent data, using a Generalized Additive Mixed Effects Model (GAMM).

The major male moult occurred earliest in the southern CMAs, and occurred later in the northern CMAs. The peak day in CMA H was March 10th, and the peak day in CMA A was May 2nd Estimates for CMAs I and J were not reliable due to data limitations. This variation in moult timing appeared to occur continuously throughout the coast, likely based on temperature, and therefore a clear delineation of stocks was not evident.

Maturity Differences

Approach and Summary

A literature review of variability in Dungeness Crab maturity at age was conducted as maturity data is not collected during surveys. Variability in Dungeness Crab maturity is not evident throughout their range. Some variability in rate of egg extrusion is apparent, with crabs in colder temperatures (e.g., Alaska) not extruding eggs annually (Swiney and Shirley 2001). It is unclear if this variability also occurs in BC.

Morphometrics

Approach and Summary

A literature review of morphometric variability in Dungeness Crab was conducted. Morphometry varies between megalopae collected in the Strait of Georgia and those collected on the West Coast of Vancouver Island (DeBrosse et al. 1990). It has been suggested that this variability is due to temperature. Morphometric differences have been observed between adult crabs collected in Alaska and Boundary Bay, BC (Weymouth and Mackay 1936).

Table 1. Summary of evidence reviewed for determining Dungeness crab stock structure in BC.

Characteristic	Data source	Description/ method	Result	Relevance to crab stock decision	Uncertainty	Conclusion	Future work/gaps
Genetics	Literature review	Review of available information on genetic differentiation	Evidence of genetic connectivity with some evidence of genetic structure in some fjords, but data is limited spatially and temporally. Evidence of genetic isolation in some inlets such as Hood Canal and Allison Sound.	High	High	No large-scale pattern in genetics, but some evidence of isolation in oceanographically complex environments.	Future work needed to explore structure, particularly in complex environments.
CPUE index	Commercial catch data	Cluster analysis of standardized CPUE within Crab Management Areas as proxy for abundance. The analysis was repeated at the PFMA subarea scale as a sensitivity analysis.	Two clusters, but poor cluster fit suggests no evidence for stock delineation. Analysis at the scale of PFMA subareas also had poor silhouette scores, providing no support for delineating stocks.	Moderate	High	Not able to detect multiple stocks.	Link between abundance and CPUE has caveats.
Fishing mortality	Literature review	Different analyses throughout the coast have employed tagging studies, yield per recruit analysis, and depletion experiments to estimate exploitation rates for legal male crabs.	Exploitation rates variable but generally high.	Low	Low/ moderate	–	Estimates for some areas are ~20 years old. No estimates for CMAs G and H.

Characteristic	Data source	Description/ method	Result	Relevance to crab stock decision	Uncertainty	Conclusion	Future work/gaps
Physical limitations	Literature review	Comparison of available biogeographic classifications	Generally north/south split oceanographically at the northern end of Vancouver Island. Under some classification systems the Strait of Georgia is classified apart from the outer coast. These areas have similar environmental conditions, which could lead to similar life history traits	Low	Applicability to stock definition is moderately uncertain	Population structure may exist between these areas, but more evidence is needed.	–
Growth rates	Literature review	Literature review of growth of megalopae and adults	Growth varies generally due to temperature, but generally on gradient. Differences exist in growth schedules between offshore and Strait of Georgia megalopae.	Moderate	Moderate	No clear division based on growth rates, megalopae.	–
Age/size structure	Commercial catch data	Multivariate regression trees	No clear similarity of split over years, but poor model fits.	Moderate	High	No evidence of spatial differences in size structure.	–
Softshell timing	Commercial catch data, fishery-independent sampling, Area A sampling	Proportion of legal males that were soft by day of year by CMA	Peak softshell day is earliest in H, later in offshore areas, and latest in the north. There is limited data in I and J. Differences in softshell timing exist on a gradient, and are likely driven by environmental variables (e.g., temperature).	Moderate	Low/moder ate	Variation is largely continuous through coast, with no clear division with which to delineate stocks.	Limited winter and spring data in I and J due to survey/fishery timing.
Maturity differences	Literature review	Review of available information	No spatial differences in maturity, but some reproductive dynamics (e.g., egg extrusion)_have been shown to vary between California and Alaska, and may vary within BC, based on environmental variaiton (no evidence in BC – CA vs AK)	Moderate	High	No clear division.	–

Characteristic	Data source	Description/ method	Result	Relevance to crab stock decision	Uncertainty	Conclusion	Future work/gaps
Morpho-metrics	Literature review	Review of available information	Differences in megalopae traits between Strait of Georgia and WCVI. Differences in adult crabs between AK and Boundary Bay. Not clear what is driving morphological differences. Observations from harvesters of physical differences between inside/outside crabs (e.g., colour).	Moderate	Moderate	Cannot delineate stocks with existing information.	Limited information. Drivers uncertain.
Movement – adult	Literature review	Review of available information	Movement of adults is typically seen to be limited, although some adults do undergo large scale movements. Observations from harvesters don't align with published literature.	High	Moderate	Cannot delineate stocks with existing information.	Additional tagging studies throughout the coast across a range of habitats would improve our understanding of adult movement.
Movement - larvae	Literature review	Review of available information	Movement of larvae is complex, and can be driven by a multitude of environmental/oceanographic factors. Megalopae have the potential to travel large distances over their 4-5 month larval period, but this movement can be disrupted by oceanographic factors. Larval biology needs to be considered, as megalopae have exhibited strong swimming behaviour, and this behaviour	High	Moderate	Cannot delineate stocks with existing information.	Need for biophysical models such as those developed in Washington.

Characteristic	Data source	Description/ method	Result	Relevance to crab stock decision	Uncertainty	Conclusion	Future work/gaps
			should be accounted for in any modelling work.				

Other-Evidence Based Interpretations

The Working Paper recommended that Dungeness Crab in British Columbia should be defined as one biological stock. This conclusion was not supported by all participants in the review meeting, which led to discussion of potential alternative conclusions. Given the evidence presented in the Working Paper, an alternative conclusion was proposed that

1. there is sufficient evidence to define Dungeness Crab in offshore waters and waters with relatively low biophysical complexity (i.e., environments with a high probability of oceanographic mixing) as one biological stock, and
2. there is insufficient evidence to conclude whether or not Dungeness Crab in inside waters (e.g., the longer fjords and inlets characteristic of much of the coastline of British Columbia) operate as part of the same biological stock, as part of a single separate stock, or as multiple separate stocks.

This alternative conclusion is consistent with the Terms of Reference of the Working Paper, which specified an objective to “evaluate the stock definition for Dungeness Crab in BC…”, but which did not explicitly state that stocks must be *delineated*. The proponent submitted that the weight of evidence supports the alternative conclusion due to scarce data from fjords and inlets and evidence of strong genetic differentiation (with high uncertainty) in two sampling locations in the Pacific Northwest (Allison Sound and Hood Canal). The genetic research on Dungeness Crab in BC relies on eight sampling locations, and as summarized in the Working Paper, “suggests that there are isolated populations in bathymetrically complex environments such as fjords”. No genetic samples were included from inlets and fjords on the Central Coast (Crab Management Area B) and one genetic sample was included from an inlet in the inside passage of Vancouver Island (Crab Management Area G). The alternative perspective presented during the review meeting proposed that there is sufficient evidence to conclude, with high uncertainty, that more than one biological stock of Dungeness Crab may exist in BC but insufficient information exists to delineate between stocks.

Sources of Uncertainty

- Genetic information is spatially limited and likely out of date at this point (i.e., studies only used a few loci, whereas a more comprehensive genomic approach would likely be used now).
- Using commercial data introduces some issues due to potential hyperdepletion in catch rates (Richerson et al., 2020) . Currently there is no standard coast-wide fishery independent sampling; expansion of independent biological sampling programs could reduce this uncertainty.
- Literature suggests only small scale movement of adult Dungeness Crabs, although stakeholder experience suggests this may not fully capture the degree of movement, particularly when habitats are unsuitable.
- Movement patterns of larvae are uncertain and require modelling, which must incorporate larval biology and behaviour (i.e., megalopae have exhibited strong swimming behaviour and are not passive particles).
- Variability of life history through space is not well studied, and growth rates/moult times likely vary on more of a gradient than a hard boundary. Additional information and more sophisticated life history modelling would be a benefit.

- The scale and location of available data is variable, and local knowledge (including from First Nations, commercial harvesters, and others) is not always captured in the available academic literature. Fine-scale data collected by First Nations and others could be used to explore differences in moult timing, size structure, etc.
- Understanding population dynamics in Alaska and the California current will be important as it is likely that the Dungeness Crab stock crosses international borders.
- Failure to account for population structure in future assessments can lead to biased assessments, which can then lead to overexploitation or underutilization of the fishery. Future assessments should therefore account for spatial heterogeneity, and continue to investigate population structure.
- Simulation studies indicate that applying harvest based on incorrect spatial structure can lead to overharvest and foregone yield, particularly when connectivity is poorly understood (Goethel and Berger 2017). The use of spatial population models has been shown to be more robust to uncertainty in population structure than models that are panmictic or spatially aggregated (Bosley et al. 2021).

CONCLUSIONS AND ADVICE

- Overall, there is evidence of spatial heterogeneity in Dungeness Crab, but there is insufficient information to delineate multiple stocks at this time. However, data are limited spatially and temporally, which leads to uncertainty about the lack of multiple stocks, most notably in fjords where uncertainty is particularly high.
- At this time, it is recommended that Dungeness Crab in BC be defined as one stock.
- There are a number of research needs that will help to understand finer scale Dungeness Crab population structure and dynamics. In particular:
    - Development of empirical indices of recruitment trends, for example using light trap index station data.
    - Biophysical larval dispersal models that incorporate larval behavior, pelagic larval duration, mortality, and other parameters.
    - Genetic and genomic studies that incorporate spatial and temporal (i.e., interannual) variability, with a focus on filling existing spatial gaps (North Coast, Central Coast, Haida Gwaii, northeastern Vancouver Island).
    - Tagging studies to understand the movement of adult crabs at various scales (e.g., between and within habitats, management areas, and across international borders).
    - Work to understand the potential differentiation of crab populations in fjords, incorporating all of the methods described in the previous bullets.
    - Work to engage and reconcile the available scientific information with local knowledge and experience.
    - Simulations and sensitivity analyses can be used to test alternate scenarios about stock structures.
    - Understanding the relative contributions of habitat vs. human proximity to CPUE.
    - Reconciling spatial uncertainty

OTHER CONSIDERATIONS

Much of the variability in Dungeness Crab phenotypic characteristics is thought to be driven by environmental differences, particularly temperature. Changing ocean conditions, including increases in temperature and decreases in dissolved oxygen, are likely to affect Dungeness Crab population dynamics and could have implications for stock structure.

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