Sentinels of Change

2023 Light Trap Network Report

Prepared for the Sentinels of Change 2023 Community Partners

Jeannine Georgeson at her trap in Whaler Bay - Photo by Shanna Baker.

Report prepared by Heather Earle and Lauren Krzus | Hakai Institute

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SENTINELS OF CHANGE

Hakai

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Project Information

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Key Points

- 2023 was the second year of the Sentinels of Change light trap network, a network of community partners that uses light traps to monitor Dungeness crab megalopae (last larval stage) along the coast of British Columbia.
- Numerous communities and organizations participated, with 30 light trap stations sampling consistently through the season, 37 partner organizations, and ~250 participants taking part in 2023.
- Partners operated and checked light traps from April 15th to September 1st, 2023.
- 229,166 Dungeness were recorded across the network during the 2023 season, with peak larval arrival occurring during the month of July.
- Catch was highest in the lower mainland, southern Gulf Islands, and southeast Vancouver Island with the largest catches occurring at traps in Horseshoe Bay, West Vancouver, and Indian Arm.
- The largest megalopae by carapace width were found early in the season and gradually declined in size towards September.
- In July 2023, Hakai staff at the Marna Lab at the Quadra Field Station successfully piloted the collection, transportation, and maintenance of Dungeness crab megalopae in mesocosms. Further experiments are being planned to investigate the effects of ocean acidification, temperature, and hypoxia on Dungeness larvae.
- In August 2023, six light trap stations collaborated with DFO's Aquatic Invasive Species Program to collect and filter water samples from light traps to look for invasive European Green Crab (*Carcinus maenas*) larvae using DNA analysis.
- Light trap coordinators and Hakai project leads debriefed at the Quadra Centre for Coastal Dialogue in October 2023.

Background

2023 was the second year of data collection within the Sentinels of Change light trap network, a project initiated as an expansion of an existing network in Puget Sound run by the Pacific Northwest Crab Research Group (PCRG; Buckner et al. 2022). Both networks use light traps to track the arrival and abundance of the last larval stage of Dungeness crab (*Metacarcinus magister*), the megalopal stage. Together, these initiatives bring together scientists, managers, and communities to monitor patterns of larval Dungeness arrival and abundance across a large area, from as far north as Prince Rupert in British Columbia to the bottom of Puget Sound in Washington.

This work presents an opportunity to improve our understanding of patterns of larval Dungeness dispersal, population and recruitment dynamics, and responses of different Dungeness life stages to the impacts of climate change. These data also hold potential as a forecast tool for crab managers along the coast as megalopal abundance elsewhere has been shown to strongly correlate with commercial crab landings four years down the line (Shanks et al., 2010). Dungeness crab hold enormous ecological and cultural importance throughout their range and are among the highest value single-species fisheries in both the US and Canada (Norton et al. 2023). They are an important food item for many Indigenous communities and have been for millennia (Ban et al. 2017; Burns et al. 2020). The data and connections produced by this transboundary work are critical to fill information gaps and build tools to assist managers in maintaining healthy stocks in the face of climate change and the increasing pressure on crustacean fisheries worldwide (Boenish et al. 2022).

In 2023, we continued our efforts to collect high quality data while also expanding the Sentinels of Change network beyond the Salish Sea to other areas of the BC coast. We partnered with new organizations and communities and saw a high return of the partners that took part in 2022. We also piloted additional research that leverages the light trap network to investigate other important questions about future impacts to Dungeness populations including the impacts of climate change and invasive species. The outcomes of the 2023 data collection efforts are detailed in this report.

Sites and Methods

From April 15th to September 1st, 2023, community partners deployed and monitored light traps at 30 sites across the coast (Figure 1). This time period covers the known larval delivery season of Dungeness megalopae and is consistent with PCRG protocols. Traps were typically checked (emptied) every two days and each time Dungeness megalopae and first juvenile instars were counted and up to 30 were measured using a photo technique. Other species were identified and counted within the abilities and capacity of each group at each station.

This work takes place across the traditional territories of numerous First Nations who have stewarded their lands and waters for millennia.

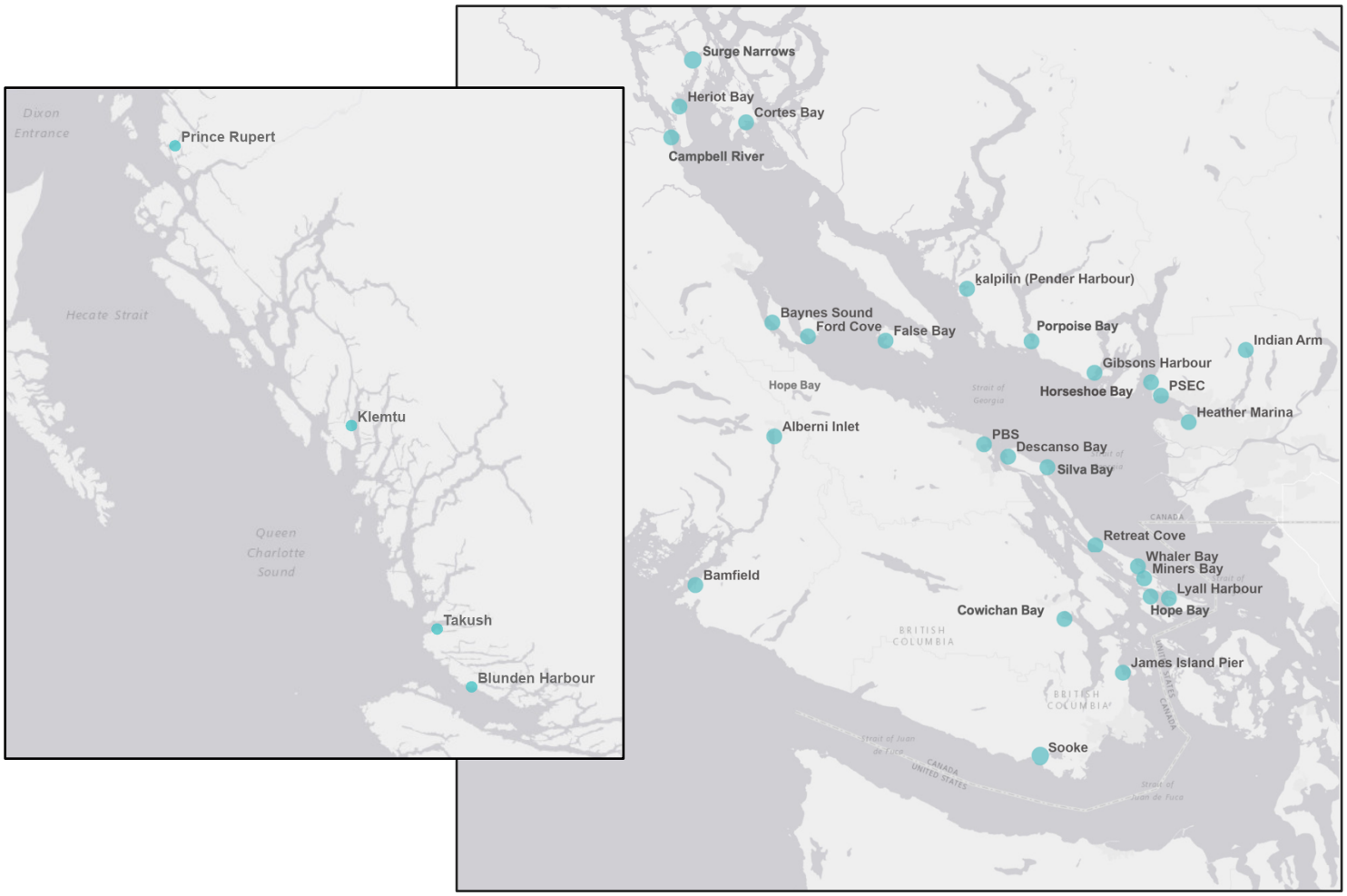


Figure 1. 2023 Sentinels light trap sites along the Central and North coast of BC (left) and along Vancouver Island and the Salish Sea (right). Note that a small portion of sites were pilots in 2023 and sampling was irregular and infrequent.

Partners

In 2023, the light trap network had more than 250 participants from a wide variety of organizations and communities, including:

Wigwam Inn, Tsou-ke Marine Team, Tsleil-Waututh First Nation, Tsawout First Nation, Surge Narrows School, shíshálh Nation, Shaw Centre for the Salish Sea, Sewell's Marina, Saturna Ecological Education Centre, SD64, SD72, Quadra Island Community, Pacific Science Enterprise Centre, Powell River Community, Pacific Biological Station, Page's Resort & Marina, Pender Island Conservancy, Pender Harbour Ocean Discovery Station, Ocean Wise, Nicholas Sontag Marine Education Centre, Mayne Island Conservancy, Lasqueti Island Nature Conservancy, Institute of Ocean Sciences, Kitasoo Xai'xais Stewardship Authority, Institute for Multidisciplinary Ecological Research in the Salish Sea, Hornby Island Natural History Centre, Hornby Island Diving, Ha'oom Fisheries Society, Gwa'sala-'Nakwaxda'xw Nations, Galiano Conservancy Association, Gabriola Power Squadron, Gabriola Island Community, Friends of Cortes Island Society, Fisheries and Oceans Canada in Prince Rupert and Port Alberni, False Creek Friends Society, Cowichan Bay Maritime Centre, Cowichan Estuary Restoration & Conservation Association, Conservancy Hornby Island, Centre for Indigenous Fisheries, Campbell River Aquarium, Bamfield Marine Science Centre, Átl'ka7tsem/Howe Sound Marine Stewardship Initiative, Association for Denman Island Marine Stewards.

June 2023: A new light trap at the Spirit Lodge dock in Klemtu, Kitasoo Xai'sais First Nation Territory - Photo by Heather Earle.

Observations and Data

Key Observations

- Overall, larval Dungeness counts were much higher in 2023 than in 2022. A total of 229,166 Dungeness was recorded (megalopae and first juvenile instars) in 2023, compared to 22,725 in 2022.
- Peak larval arrival across the network occurred during the month of July.
- The Horseshoe Bay light trap lead by the Átl'ka7tsem/Howe Sound Marine Stewardship Initiative caught the most Dungeness across the season with 83,627.
- The Indian Arm light trap, operated by the Wigwam Inn, caught the most Dungeness in one night with 23,813.
- Larvae were first caught around the south end of Vancouver Island and the last were caught at sites in the lower mainland.
- Initial data indicate sea surface temperatures were higher overall in 2023.
- Temperatures tended to be higher at more northern sites and slightly cooler in the more southern portions of the network.
- At some sites, peak larval arrival coincided with the hottest times of the season. In some cases, this corresponded with high larval mortality in traps leading us to reduce fishing effort and adapt our equipment and protocols to mitigate this.

Timing of Megalopae Arrival

In 2023, the pattern of megalopae arrival was somewhat similar to what was observed in 2022. Megalopae were first caught in the James Island Pier light trap on Saanich Peninsula on May 4th, 2023. (Table 1, Figure 2). This was quickly followed by their arrival in light traps in the Southern Gulf Islands and then along the east coast of Vancouver Island followed by the Sunshine Coast and then the lower mainland in mid-June. They were caught last in Indian Arm, at the far end of the Burrard Inlet, as late as June 26th.

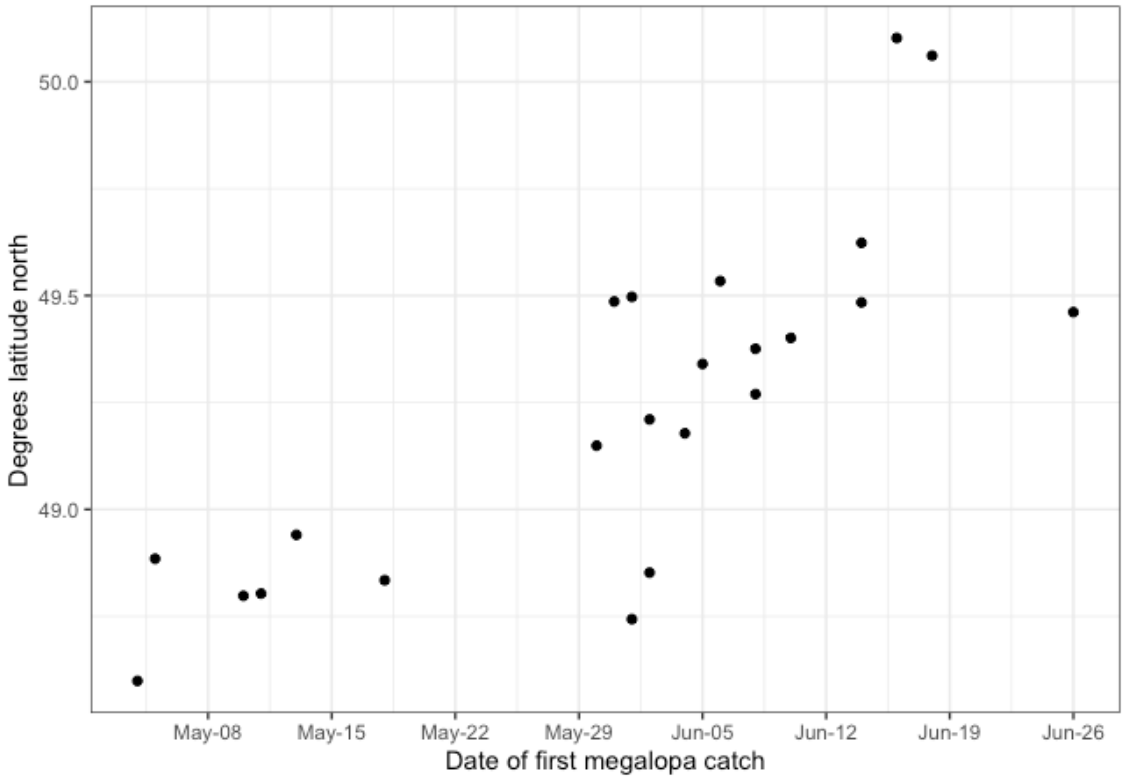


Figure 2. Comparison of first megalopae catch dates at each site latitude. Note that sites that joined the network late this year (after April 15th) are removed from this graph to keep comparisons consistent. This includes: Bamfield, Sooke, and Powell River. Prince Rupert, Surge Narrows, and Port Alberni did not catch crabs in 2023.

Table 1. Total catch and first catch summarized by light trap site and year. Note that some sites had equipment malfunctions or joined the network late and therefore may have missed earlier Dungeness arrival as well as later season catch (noted with asterisks). Grey cells indicate sites that did not have a trap in the water in a given year. Although not reflected here, high numbers of larvae (tens of thousands) were observed in Porpoise Bay in ʔahtulich (Sechelt Inlet) in shíshálh swiya/territory in 2023.

Light Trap Site	First Catch 2022	First Catch 2023	Total 2022	Total 2023
Alberni Inlet		NA		0
Bamfield		May 18*		14
Baynes Sound		June 6		535
Boot Cove	July 1*		438	
Campbell River		June 5		1,227
Cortes Bay	June 12	June 18	75	8
Cowichan Bay	June 27	June 1	421	4,936
Descanso Bay	June 14	June 4	274	3,445
False Bay	July 9	May 31	37	2,061
Ford Cove	July 4	June 1	396	329
Gibsons Harbour		June 10		568
Heather Marina	June 22	June 8	1,207	329
Heriot Bay	June 23	June 16	11	175
Hope Bay	June 4*	May 11	5,015	2,496
Horseshoe Bay	June 20	June 8	4,081	83,627
Indian Arm		June 26		78,893
Institute of Ocean Sciences	May 25		83	
James Island Pier		May 4		1,712
Lyall Harbour		May 10		205
Miners Bay	May 11	June 2	4,550	8,343
Pacific Biological Station	June 20	June 2	105	105
Pacific Science Enterprise Centre	June 20	June 5	3,351	34,728
kalpilin (Pender Harbour)	June 16	June 14	110	584
Porpoise Bay		June 14		547
Powell River Marina		August 22*		1
Prince Rupert		NA		0
Retreat Cove	May 9	May 13	52	63
Silva Bay	June 7	May 30	1,754	2,600
Sooke Harbour		May 12		21
Surge Narrows	June 10	NA*	20	0
Whaler Bay	May 12	May 5	587	334
Winter Cove	May 9		163	

Megalopae Abundance

Across the light trap network, we caught a total of 229,166 Dungeness crabs over the 2023 season, up tenfold from 2022 when we caught 22,725. This number includes both megalopae and first juvenile instars (megalopae often moult into juveniles inside the trap). Like 2022, the majority of the catch occurred between mid-June and late July in 2023. Catch diminished through August until traps were removed from the water on September 1st (Figures 3 and 4).

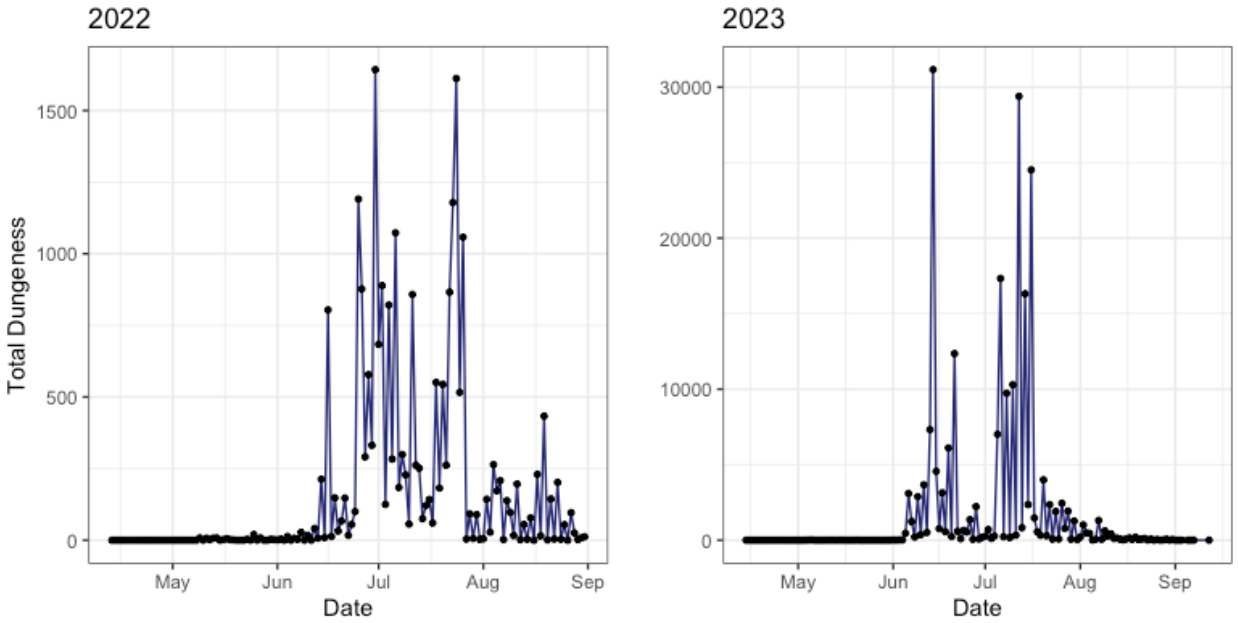


Figure 3. Total Dungeness (megalopae and first juvenile instars) caught across all sites by year. Note the differences in the vertical axes between years.

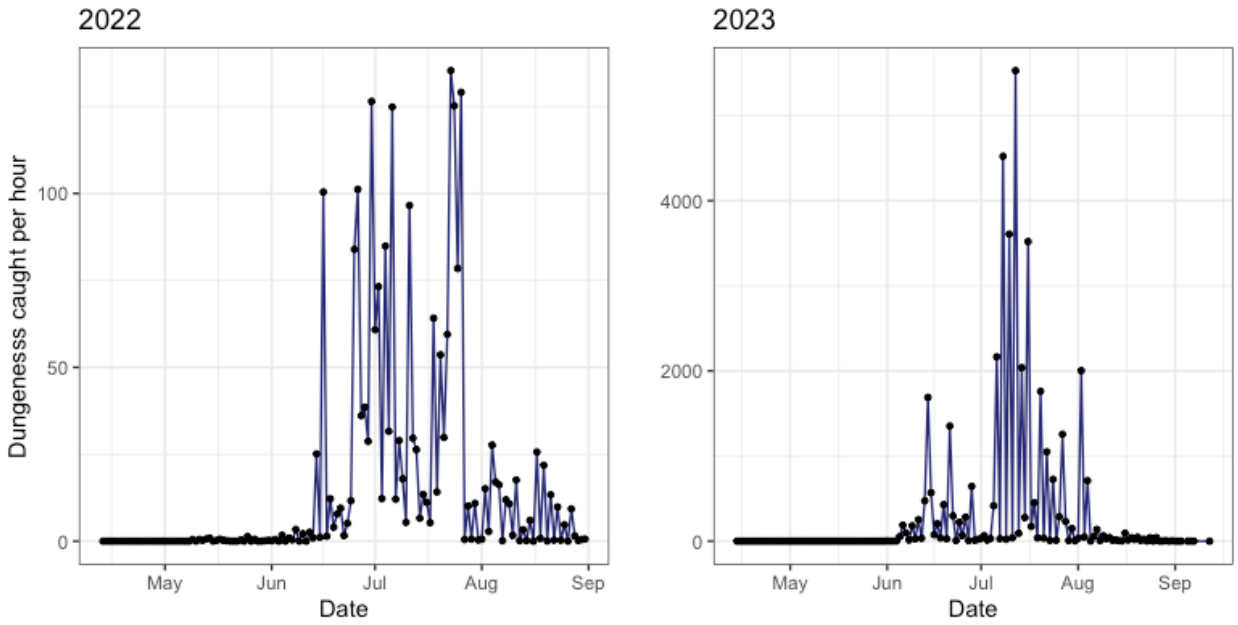


Figure 4. Catch per unit effort (CPUE) (crabs per hour) across all sites by year. CPUE was calculated as the number of crabs caught per hour when a trap is "fishing" (lights on) and thus accounts for variation in fishing effort across sites. Note that effort changed across the season as we adjusted the timers with sunset and sunrise through the season. **Note the different vertical axes between years.**

Megalopae Catch by Site

Similar to 2022, the majority of the 2023 catch occurred at a few sites, this time largely in the lower mainland (Figures 5, 6, and 7). These sites included Horseshoe Bay, the Pacific Science Enterprise Centre (PSEC; West Vancouver), and Indian Arm (Burrard Inlet). Together, these three sites caught 197,248 Dungeness, representing 86% of the total catch in 2023. The high numbers at these three sites are remarkable considering that fishing effort (the time the trap was turned on) was also drastically reduced at these sites during the month of July to prevent Dungeness mortalities with the very warm sea surface temperatures in 2023.

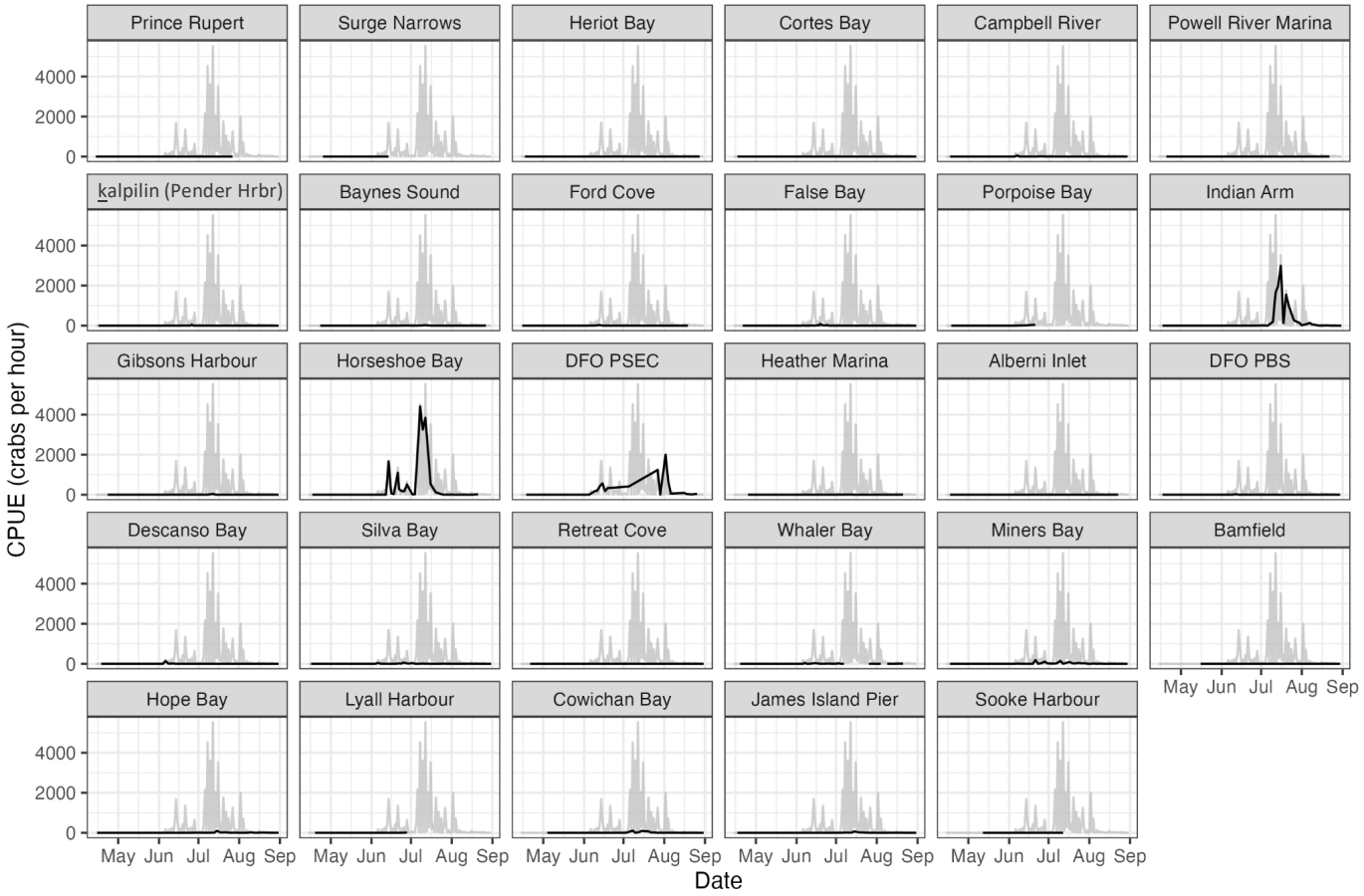


Figure 5. Dungeness CPUE (crabs per hour) shown at each site in the network (black lines). Sites are ordered by latitude with most northern sites at the top and most southern at the bottom. The grey lines are the same in each panel and show the total CPUE across all sites.

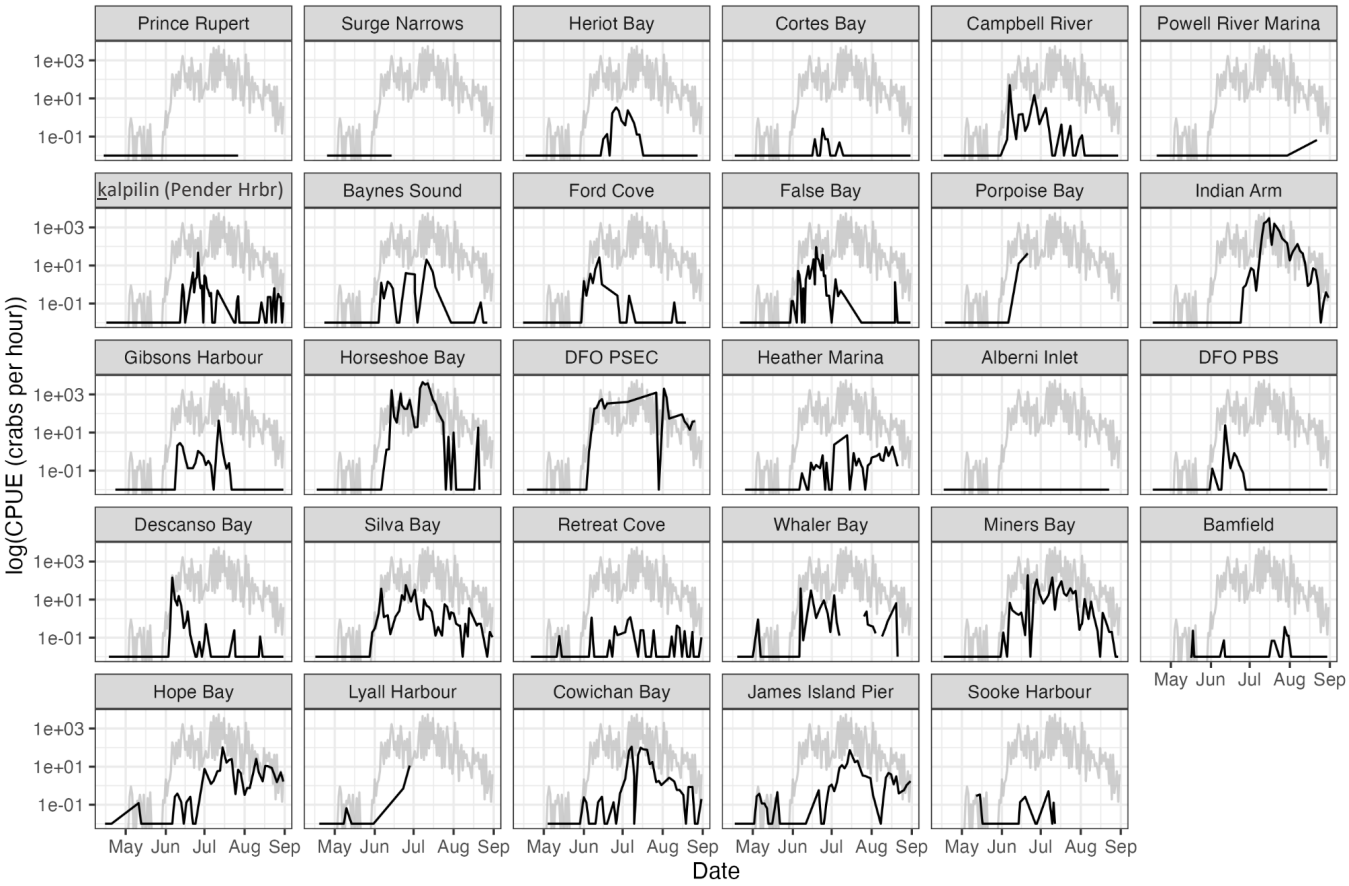


Figure 6. Dungeness catch per unit effort (crabs per hour) shown at each site in the network (black lines). In this figure, the data are displayed on a logarithmic scale so that trends across sites with lower catch can be seen. Sites are ordered by latitude with most northern sites at the top and most southern at the bottom.

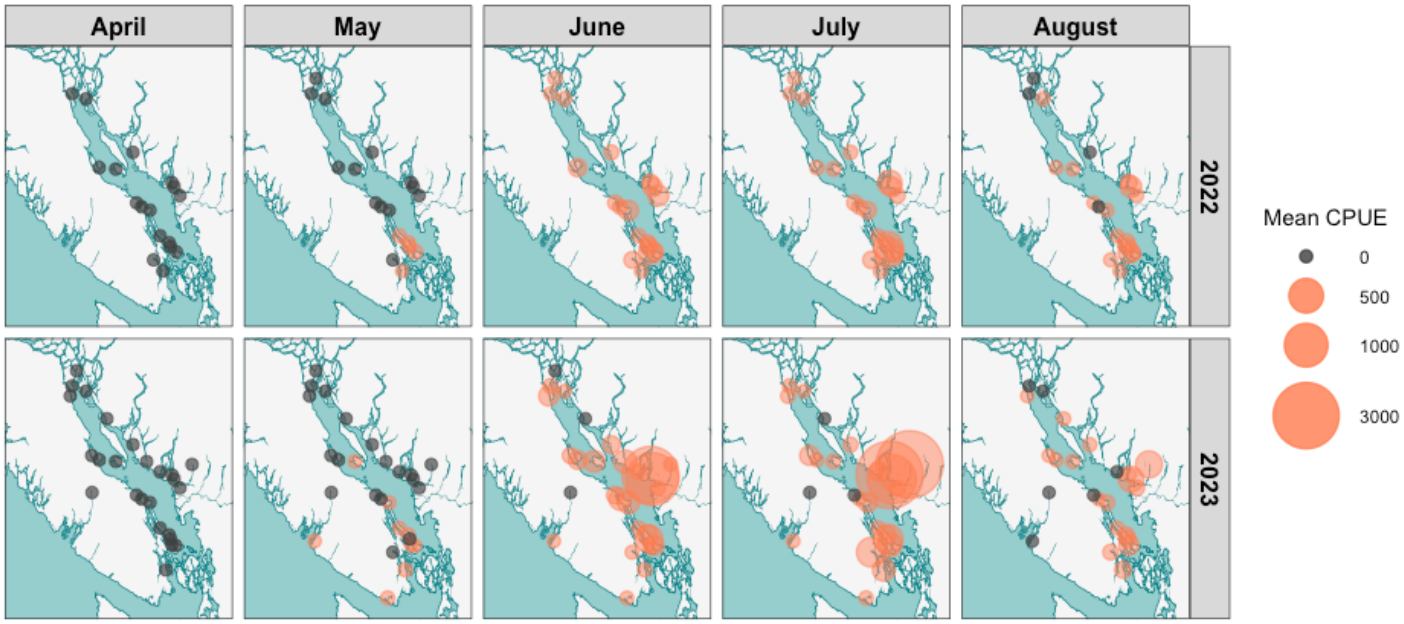


Figure 7. Dungeness catch per unit effort (crabs per hour) averaged by month (mean CPUE) shown at each site in the network for 2022 and 2023. The size of each bubble represents the mean CPUE for each site in that month. This map excludes the sites that did not collect more than one week of data in either year, as well as the Prince Rupert site which caught no Dungeness in 2023.

Catch Across the Salish Sea

Unlike last year, sites across the international border in the southern portion of the Salish Sea did not see as many larvae as the Sentinels network in 2023. Like our network, their peak larval arrival was in the month of July with some of their largest catches occurring in the vicinity of Boundary Bay in the lower mainland. This pattern fits with what was observed in the Sentinels network, where the largest catches were all in the lower mainland in the month of July.

Megalopae Size

In 2023, we took a digital approach to megalopae measurements. When Dungeness megalopae were present, partners placed up to 30 into a standardized black tray with a scale bar and took an overhead photo with as little tilt as possible. These images were then imported into an image analysis software, ImageJ, where carapace widths were measured. Although there are sometimes issues with tilt and glare with the photos, this approach has been effective in reducing monitoring time and effort for partners and improving accuracy of measurements. In future years, improvements will be made to the equipment to reduce glare and tilt in the photos.

Figure 8 shows the average measurement of all megalopae measured on a given date at a given site across the network. Although less abundant, the largest carapace widths were measured from megalopae caught in the months of May and June with sizes appearing to decline through the remainder of the season (Figure 8). The largest megalopa of the season measured 4.55mm (June 18th) and the smallest was 1.71mm (June 21st).

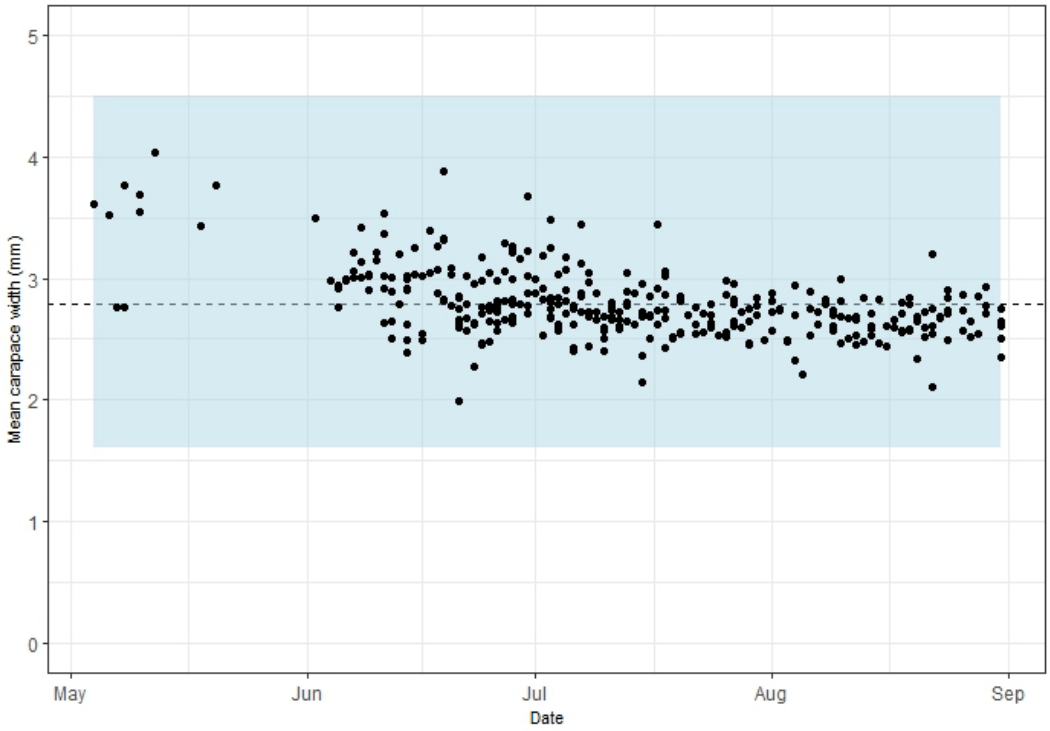


Figure 8. Carapace widths of megalopae measured from all sites across the season. Each dot is an average of all megalopae measured on each date at each site. The dotted lines show the average width through the season across all observations, and the shaded rectangle shows the typical range of Dungeness carapace widths from published literature (Debrosse et al., 1990).

In Figure 9, we can see an initial visualization of how megalopae carapace widths change through the season at each site. The blue violin plots display the size distribution of megalopae measured each month. Note that many sites did not catch megalopae in all months and in some cases, there were very few megalopae caught in a given month and thus the sample sizes are quite small in those instances. As well, photo quality tended to vary and so although some sites may have caught megalopae and photographed them, they couldn't always be measured.

Data from some sites seem to exhibit a gradual decline in megalopae carapace width, specifically James Island Pier, Retreat Cove, and Heather Marina (Figure 9). At other sites, carapace widths appear to remain consistent through the season. Further investigation using statistical analyses is needed to explore and understand these trends.

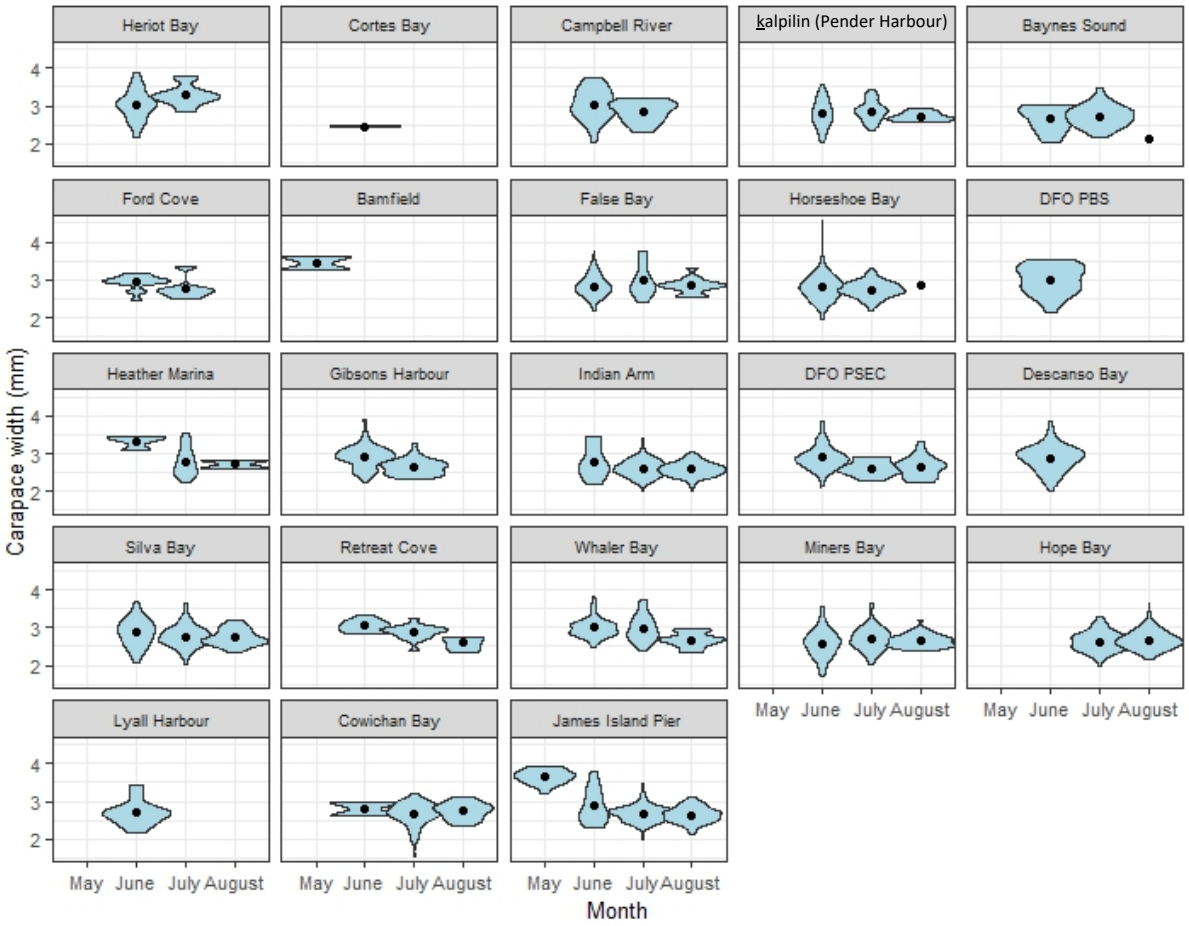


Figure 9. Distribution of carapace widths by month at sites with measurable megalopae in 2023. The black dots represent the median carapace width in each month and the blue shaded areas show the distribution of carapace widths. The wider sections of the violins indicate sizes that occurred more frequently than the narrow sections. Sites are ordered by latitude with most northern sites at the top.

Sea Surface Temperature

We used Onset HOBO TidbiT MX2203 temperature data loggers to record sea surface temperature at each light trap site. Loggers were suspended 0.5 m below the surface from floating docks adjacent to light traps and were programmed to record the water temperature every 10 minutes for the entirety of the season. Figure 10 shows temperature trends by site across the season, organized by latitude (northern sites on top and southern sites on the bottom). Recorded temperatures tended to be warmer at more northern latitudes in the Salish Sea. Overall, sea surface temperatures in 2023 exceeded those recorded in 2022, especially in more northern latitudes.

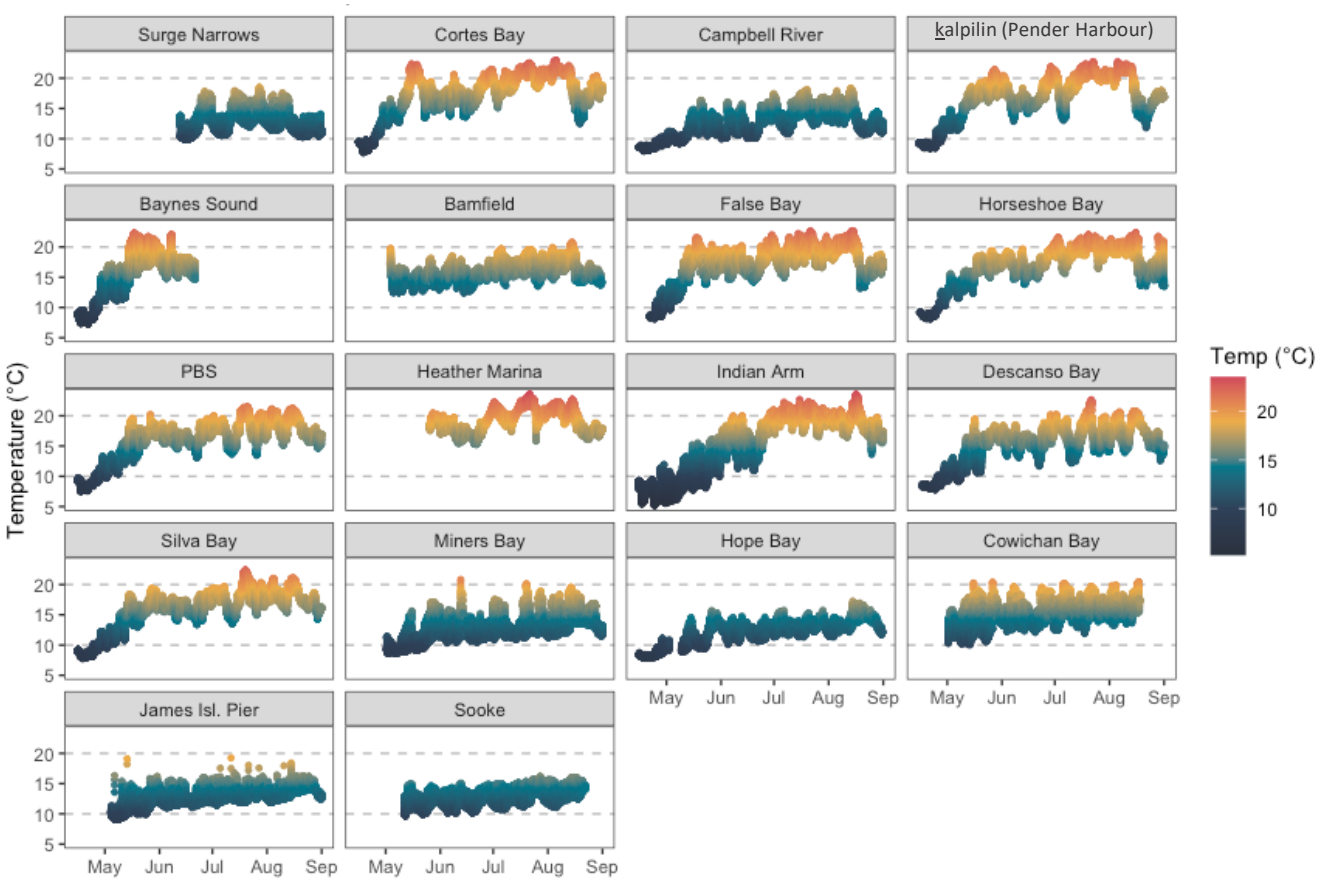


Figure 10. Temperature recorded at each light trap site from April 15th - September 1st, 2023, descending by latitude from top to bottom. Note that data for some sites are missing as temperature loggers were lost at several sites in 2023 or loggers had not yet been returned to Sentinels coordinators at the time this report was released.

Temperature and Peak Larval Arrival

Figure 11 shows the CPUE through the season at each site coloured by average sea surface temperature on that date. Here, we see that some sites experienced peak larval delivery when sea surface temperatures were near their warmest of the 2023 season, notably Heather Marina, Horseshoe Bay, Indian Arm, and Pender Harbour.

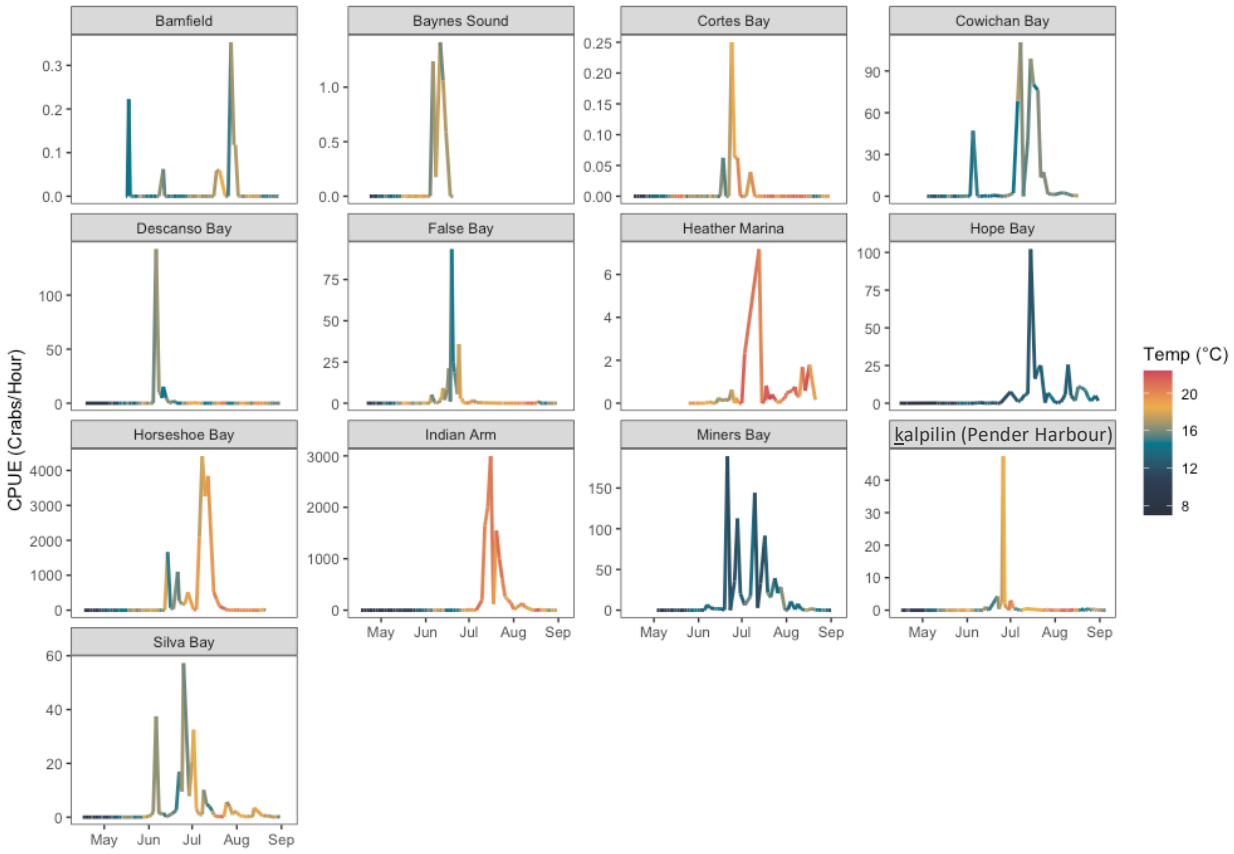


Figure 11. CPUE (crabs/hr) at each light trap site coloured by average sea surface temperature, descending by latitude from top to bottom. Note that the y axes differ across plots as CPUE varies considerably across sites. Some sites are not included in this plot if they a) did not catch Dungeness in 2023 or b) temperature data were not yet retrieved at the time this report was released.

Challenges in 2023

Several challenges emerged in 2023 requiring community and project coordinators to respond and adapt through the season. Globally, sea surface temperatures in 2023 were among the highest on record with large areas reaching anomalies of 3°C warmer than normal (NASA 2023). Warm water is a stressor in itself to marine organisms but also has a reduced capacity to hold oxygen which further threatens survival (Gruber 2011). At times, we experienced high Dungeness mortality at several sites, specifically in the lower mainland (Horseshoe Bay, PSEC, Indian Arm) when high larval delivery coincided with anomalously warm water temperatures (Figure 11).

To respond to these events, we worked with site leads to make adjustments to mitigate mortality including: reducing fishing time, in most cases to every other night of fishing and at times to as little as 1 hour of fishing per night; encouraging participants to check the trap as early as possible to reduce larval exposure to high temperatures; introducing bubblers into the traps to improve oxygenation; and sometimes stopping fishing altogether when water temperatures were too high. In July, we conducted a trial on Quadra Island to investigate the impacts of aerators on Dungeness catch and survival. Further research is required as larvae were not abundant enough at that time to answer our questions. During our annual postseason debrief with community coordinators, we discussed challenges around mortality and explored potential solutions. We are continuing to investigate other trap and protocol modifications to reduce mortality as we anticipate many more hot summers to come (Johnson and Lyman 2020).

We also experienced some equipment challenges in 2023 (Table 2). We are currently working to implement changes to improve equipment for the 2024 season. Thank you to all participants that provided feedback and suggestions during the 2023 season!

Table 2. Equipment challenges and identified/implemented solutions.

Problem	Solution
Lights burning out (resistors overheating)	Wrap dowel in aluminum to disperse heat
Losing weights on cod end	Add a sacrificial zinc anode
Difficulty seeing larvae in measurement trays	Change tray color and design
Leaking light units	Leak tests prior to season, additional sealant at seams.
Timers difficult to program	Improve protocol print-outs and videos
Insufficient water exchange in trap	Add holes to top & bottom with mesh to improve flow

Other Species

Along with Dungeness megalopae, many other interesting species are attracted to the light traps. Documentation of other species varied with the capacity and interest of participants at each site, with some sites recording other species regularly and in detail while others only recorded Dungeness crab. Since 2022, we have had an iNaturalist community project for participants to upload pictures of unknown (or known) species caught in light traps. iNaturalist is an online social network with a crowdsourced species identification system. In 2023 alone, the light trap network contributed 166 observations and identified 50 species! Thank you to everyone who contributed to the iNaturalist community project.

To explore the Sentinels of Change iNaturalist page visit:
https://www.inaturalist.org/projects/sentinels-of-change-light-trap-monitoring

Species caught in light traps, photographed by various participants, and identified on iNaturalist.

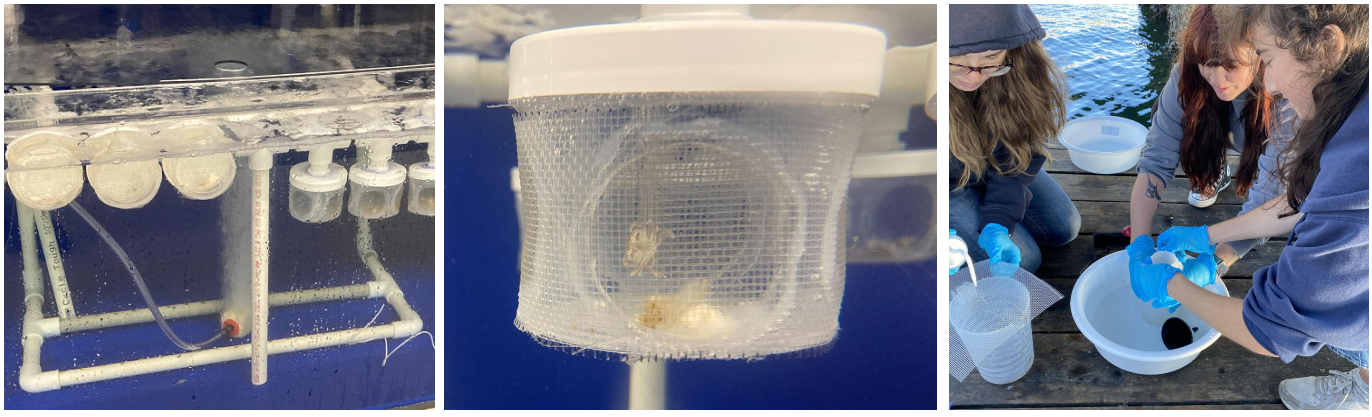
Additional Work in 2023

Mesocosm Experiments

In July, the Marna Lab at the Hakai Institute on Quadra Island conducted a pilot study to determine if Dungeness megalopae could be collected, transported, and maintained in wet lab mesocosms. The wet lab team was successful in transporting ~1,000 megalopae from Horseshoe Bay to Quadra Island where they were maintained for 21 days in custom made 'crabitats' (pictured below). During this time, they were fed a diet of mussels freshly harvested from the Hakai Shellfish Raft in Hyacinthe Bay and their respiration, molting, and growth was successfully monitored. As Dungeness larvae are vulnerable to ocean acidification, increasing temperatures, and low dissolved oxygen levels, future work in the Marna lab in simulated climate change conditions will provide insight into how local populations of Dungeness will fare in a changing ocean.

European Green Crab Detection

In August and September 2023, partners at 6 sites (Cortes Island, Descanso Bay, Ford Cove, Pender Harbour, Sooke Harbour, and James Island Pier) worked with DFO's Aquatic Invasive Species program to pilot a project to detect invasive European Green Crab (EGC; *Carcinus maenas*) larvae in light traps. Unlike Dungeness megalopae, EGC larvae are too small to identify visually, so partners collected and froze water samples from the light traps for genetic analysis to determine if they are present.



Left: Crabitats set up in a mesocosm in the Marna Wet Lab; middle: a zoomed in crabitat with a crab inside; and right: participants at James Island Pier light trap retrieving a water sample for genetic analysis to look for EGC, photo by Christine Spice.

Adult EGC populations are well established in Sooke basin but have not been detected at the other participating sites in the Salish Sea. Therefore, we anticipated that we would detect EGC in the Sooke light trap only. Initial results from genetic analyses align with these expectations as Sooke was the only site where EGC DNA were detected. These results show promise as a proof of concept for this approach and the potential for light traps to serve as early detection for this invasive species. EGC pose serious risks to the economy, ecology, and cultural food sources in the Salish Sea and this work will continue into 2024 and be an important component of the Sentinels of Change program.

Media and Outreach

2023 articles and blog posts

- Friends of Cortes Island: '2023 Project Highlights'
- Mayne Island Conservancy: 'Community Within Coastal Science' by Justine Apostopolous
- CERCA: 'Sentinels of Change: Larval Crab Light Trap Monitoring' by Bill Heath
- Hakai Magazine 'Shining a Light on Baby Crabs' by Spoorthy Raman

School and Community Presentations

We reported back to communities upon request following the 2023 data collection season both virtually and in person. We put together presentations to summarize findings across the network and at specific sites, allowing time for discussion and questions. We love connecting with our participants and communities; let us know if you would like us to give a presentation in your community before the 2024 season!

Postseason Gathering

Following our 2023 data collection season, we again invited light trap coordinators to join us at the Quadra Centre for Coastal Dialogue, on Quadra Island to debrief and learn from another season together. Attending partners were given an overview of the season and how initial results compare to the year prior. We spent time discussing challenges, lessons learned, and brainstorming solutions. Due to space limitations, we unfortunately could not invite all light trap participants.

Postseason gathering, Quadra Island Centre for Coastal Dialogue, October 2023. Photos by Shelby McKay (left) and Justine Apostopolous (right).

Takeaways and Future Years

We saw continued success of the light trap network in 2023. In our second year, we had high levels of community participation with 95% of our 2022 partners returning and 12 new additional sites established, increasing the spatial extent of our network and data collection. New challenges did emerge in 2023, presenting us with the opportunity to improve our equipment and protocols to strengthen the project in coming years. We saw high engagement from our community partners who were dedicated to quality data collection and problem solving through the season. Partners also went the extra mile to engage more people by including school groups, delivering community presentations, and communicating about the project on social media to reach a wider audience.

As we continue with the project, we look forward to carrying out further data analyses to identify patterns of larval Dungeness dispersal and abundance and explore some of the factors driving these patterns. We are not yet in a place to compare catch to commercial landings, but this will be a strong focus in the years to come as we continue to collect data and start developing forecast models. We will continue to work closely with our many partners and with the PCRG to produce a high quality, transboundary dataset that will be useful to Dungeness crab managers across the coast.

What's Next?

Several new sites are confirmed to join for the 2024 season, and we look forward to many of our 2023 partners returning for a 2nd or 3rd season. In 2024, we will continue working with DFO to collect water samples from light trap catches to investigate the potential for the early detection of invasive EGC. We also look forward to further experiments with the Marna Wet Lab on Quadra Island to investigate the effects of climate change on early Dungeness life stages.

2024 Dungeness pathogen investigation - PhD student, Alastair Roberts

In a rapidly changing ocean, characterising the environmental stressors and pathogens that impact key species such as the Dungeness crab is vital to conservation efforts. Some viral pathogens of crabs are known, but the effects of these pathogens on the health and survival of host larvae remain a mystery. PhD student Alastair Roberts will seek to uncover the viruses infecting Dungeness crab megalopae in the Salish Sea. Documenting the impacts, distribution and dynamics of these pathogens will enhance our understanding of the threats faced by Dungeness crab populations.

Sentinels Alliance Program

Finally, a new partnership between the Hakai Institute and University of British Columbia will soon see the scope of the Sentinels of Change program expanding within the Salish Sea. Working with communities across the region, our goal is to implement observation systems for biodiversity across a range of taxa, test hypotheses about the causes of change, and develop tools to support decision making and forecasting of biodiversity change.

The goals and the spirit of the light trap network will stay the same, but there will be additional opportunities for communities and organizations to take part in other monitoring initiatives where there is interest and capacity. You can learn more at our website (https://sentinels.hakai.org) and we will reach out directly about this in early 2024. At the heart of this work, we want the questions we ask and the lines of inquiry we pursue to align with the goals of communities and organizations in the Salish Sea, so we are looking forward to connecting with you.

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We extend a **huge thank you** to our wonderful community partners for the energy, dedication, and passion they bring to the Sentinels light trap network. We are continuously inspired by the care you show for Dungeness crab and the health of our coast. We are grateful to work and learn alongside you - this work could not happen without you!

We are very thankful for our continued collaboration with the Pacific Northwest Crab Research Group. They inspired this work and are a powerful example of what a collaborative network can do. We thank our Hakai Institute colleagues who continue to support this project with their time, expertise, and energy! We are grateful to partner with Fisheries and Oceans Canada to expand this work beyond the Salish Sea to other important areas of the coast.

Top left: Emptying the PSEC trap (Photo by David Poon); top middle: Lauren and Heather while filming the protocol video (Photo by Grant Callegari); top right: Principal investigators for the Sentinels of Change Alliance Program check a trap in Heriot Bay (Photo by Lauren Krzus); bottom left: Children on Denman Island sort through light trap catches while Lauren inspects the instars (Photo Lauren Krzus); bottom middle and right: Volunteers in Bamfield launch their trap (Photo by Hannah Schriber).

References

Ban., N.C., L. Eckert, M. McGreer, and A. Frid. (2017). Indigenous knowledge as data for modern fishery management: a case study of Dungeness crab in Pacific Canada. *Ecosystem Health and Sustainability*, **3**(8). DOI:10.1080/20964129.2017.1379887

Boenish, R., J.P. Kritzer, K. Kleisner, R.S. Steneck, K.M. Werner, W. Zhu, F. Schram, D. Rader, W. Cheung, J. Ingles, Y. Tian & J. mimikakis. (2022). The global rise of crustacean fisheries. Frontiers in Ecology and the Environment, **20**(2): 102-110, doi:10.1002/fee.2431

Burns, C.W., D. Robichaud, E. Plate, T.G. Gerwing, J. Novoa, Y. Bychkov, and R. Bocking. (2020). The effect of a spatial harvest closure area on the abundance, movement, and demographics of an intensively fished population of Dungeness crabs (Cancer magister) along Roberts Bank, British Columbia, Canada. *Estuaries and Coasts*, **43**:1556-1570.

Buckner, E., A. Cruz, J. S. Barber, K. Bosley, R. Childers, C. Cook, S. Grossman, N. Harrington, M. Nelson, E. Saas and E. Tobin. (2022). 2020-2025 Pacific Northwest Dungeness crab research guide. Pacific Northwest Crab Research Group. DOI: https://doi.org/10.1016/j.jas.2004.04.002

Debrosse, G., S. Sulkin, and G. Jamieson. (1990). Intraspecific morphological variability in megalopae of three sympatric species of the genus Cancer (Brachyura: Cancridae). *Journal of Crustacean Biology*, **10**(2): 315-329.

Gruber, N. (2011). Warming up, turning sour, losing breath: ocean biogeochemistry under global change. *Philosophical Transactions of the Royal Society A*, **360**(1943). https://doi.org/10.1098/rsta.2011.0003

Johnson, G.C. and J.M. Lyman. (2020). Warming trends increasingly dominate global ocean. *Nature Climate Change*, **10**: 757-761.

NASA. (2023, August 21). *The Ocean Has a Fever*. NASA. https://earthobservatory.nasa.gov/images/151743/the-ocean-has-a-fever

Norton, E.L., I.C. Kaplan, S. Siedlecki, A.J. Hermann, S.R. Alin, J. Newton, K. Corbett, D. Ayres, E.J. Schumacher, N.A. Bond, K. Richerson, M.A. and Alexander. (2023). Seasonal ocean forecasts to improve predictions of Dungeness crab catch rates, co-developed with state and tribal fishery managers. *ICES Journal of Marine Science*, **80**: 823-835. DOI: 10.1093/icesjms/fsad010.

Shanks, A., G.C. Roegner, and J. Miller. (2010). Using megalopae abundance to predict future commercial catches of Dungeness crabs (Cancer magister) in Oregon. *California Cooperative Oceanic Fisheries Investigations Report*, **51**: 105-118.