2022

# Test and Implement Commercial Grade Biodegradable Hinges on Dungeness Crab Traps (VA, WA, AK)

Center for Coastal Resources Management

Fishing for Energy 2020 - Submit Final Programmatic Report (New Metrics)
Grantee Organization: College of William and Mary, Virginia Institute of Marine Science
Project Title: Test and Implement Commercial Grade Biodegradable Hinges on Dungeness Crab Traps (VA, WA, AK)

| | |
|---|---|
| **Project Period** | 2/01/2021 - 1/31/2022 |
| **Project Location Description (from Proposal)** | Production of the hinges occur in Virginia with testing occurring in Washington and Alaska |
| **Project Summary (from Proposal)** | Employ commercial-grade biodegradable hinges on Dungeness crab traps to minimize adverse impacts when the traps become derelict. Project will test the durability of the hinges in both the active fishery utilizing watermen and in a simulated derelict trap mode to ensure the function as needed to be functional for fishermen and protect marine ecosystems. |

**Project Status and Accomplishments**

This project complements an earlier NFWF grant "Bio-Hinge Escape Mechanism for Dungeness Crab Traps" (NFWF 61120) that tested biopolymer technology (similar to the biopolymer used in blue crab and lobster pot escape panels) by substituting biodegradable hinges for non-degradable plastic hinges in the entrance non-return valve gate (trigger) that allows entry of crabs but blocks any exit. The previous project hypothesized that once the bio-hinge broke down, the gate would detach and fall to the floor of the pot removing the obstruction from the entrance funnel and thus allowing animals within the trap to egress. The previous project tested prototype bio-hinge robustness in the recreational Dungeness crab (Cancer magister) fishery as well as its degradation in derelict traps. An advantage of the biodegradable hinge mechanism is that it avoids complications involving biofouling since the material degrades away leaving no surface attachment sites for biofouling organisms and is a relatively simple material replacement of an existing product (plastic hinges).

Results from the previous project showed general interest from the fisher participants in the biopolymer technology. However, a common issue centered on the lack of robustness of the experimental bio-hinges in both everyday usage of the traps and even in the transportation of the traps which limited the willingness of fishers to use the technology. Many of the prototype bio-hinges were found to fail too quickly. The general conclusions from testing in both Alaska and Washington State was that the idea was promising but more research was needed on the structural design of the bio-hinge in order to meet the rigors of the Dungeness crab fishery from everyday fishing activity as well as Dungeness crab interaction with the bio-hinge mechanism (Antonelis 2020, Simmons & Heintz 2020).

The original prototype bio-hinges were constructed in-house which likely contributed to their more fragile state. This project took the recommendations from the testing in Alaska and Washington State (i.e. more robustness for added strength with a fuse or weak point for breakage over time) and incorporated them in a commercially designed, molded, and produced bio-hinge.

The primary goal of testing gear in the recreational fishery was to assess bio-hinge durability within the day-to-day handling throughout the fishing season. Catch per unit effort (CPUE) of the test pots versus standard (control) pots was conducted in Alaska but was not analyzed in Washington State since a previous 2019 CPUE Washington State study showed no significant difference in CPUE between traps with bio-hinges and those with standard plastic hinges (Antonelis 2020).

**Lessons Learned**

The key lessons from this project is to engage with local trusted organizations (Natural Resource Consulting and Sitka Sound Science Center) to help facilitate interaction and engagement with stakeholders. In addition, it is important to recruit fishers to utilize their expertise and gain valuable insight into what is important to the stakeholders. This project was informed by having fishers use the various prototype biohinges in their regular fishing activity and provide feedback on how to improve the prototypes. This resulted in a more robust biohinge as well as a two-piece snap together biohinge to promote ease of installation and replacement.

An additional key lesson is that when developing innovative mechanisms for disabling derelict fishing gear, it is important to plan for taking prototypes to commercial grade production. While prototypes can be constructed in the laboratory, it is very important to work with commercial companies for final product production. Having a commercial grade biohinge provided a significant improvement over the initial prototypes and increased the "willingness to use" component of the project.

## Activities and Outcomes

**Funding Strategy: Planning, Research, Monitoring**
Metric: FFE - Tool development for decision-making - # tools/ techniques tested
Required: Recommended
Description: Number of gear innovations that will be developed (new innovations that have not previously been tested successfully)

| | | |
|---|---|---|
| **Starting Value** | 0.00 | # tools/ techniques tested |
| **Value To Date** | 2.00 | # tools/ techniques tested |
| **Target value** | 1.00 | # tools/ techniques tested |

Note: Two types for biohinges 1) single piece and 2) two piece snap together were produced at commercial grade.

YUKON FLATS
Great Bear Lake
Great Bear
MACKENZIE MOUNTAINS
YUKON
NORTHWEST TERRITORIES
CHUGACH MOUNTAINS
Great Slave Lake
Slave
Mackenzie
Gulf of Alaska
BOUNDARY RANGES
Peace
BRITISH COLUMBIA
ALBERTA
NECHAKO PLATEAU
Edmonton
FRASER PLATEAU
COAST MOUNTAINS
Queen Charlotte Sound
COLUMBIA MOUNTAINS
ROCKY MOUNTAINS
Calgary
Vancouver
Columbia
Seattle
WASHINGTON
Portland
CASCADE RANGE
OREGON
IDAHO
Snake
Salt Lake City
GREAT BASIN
NEVADA
UTAH
Sacramento
San Francisco
CALIFORNIA
Fresno
Las Vegas
Los Angeles
Phoenix
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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|---|---|---|---|
| Final Report Narrative - Marine | Final+Report+Narrative+Marine+Programs+68684.pdf | Havens, Kirk | 04/12/2022 |
| Photos - Jpeg | bio hinge 1.jpg | Havens, Kirk | 04/12/2022 |
| Photos - Jpeg | bio hinge 2.jpg | Havens, Kirk | 04/12/2022 |
| Photos - Jpeg | PugetSound deployment 1.jpg | Havens, Kirk | 04/12/2022 |
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| Other Documents | Final Field Experiment Report 2021_Sitka_Alaska.pdf | Havens, Kirk | 04/12/2022 |

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**Final Programmatic Report Narrative**
Bio-Hinge Escape Mechanism for Dungeness Crab Traps – Phase II

**Instructions:** *Save this document on your computer and complete the narrative in the format provided. The final narrative should not exceed ten (10) pages; do not delete the text provided below. Once complete, upload this document into the online final programmatic report task as instructed.* ***Please note*** *that this narrative will be made available on NFWF's Grants Library and therefore should provide brief context for the need of your project and should not contain unexplained terms or acronyms.*

**1. Summary of Accomplishments**
*In four to five sentences, provide a brief summary of the project's key accomplishments and outcomes that were observed or measured. This can be duplicative to the summary provided in the reporting 'field' or you can provide more detail here.*

This project complements an earlier NFWF grant "Bio-Hinge Escape Mechanism for Dungeness Crab Traps" (NFWF 61120) that tested biopolymer technology (similar to the biopolymer used in blue crab and lobster pot escape panels) by substituting biodegradable hinges for non-degradable plastic hinges in the entrance non-return valve gate (trigger) that allows entry of crabs but blocks any exit. The previous project hypothesized that once the bio-hinge broke down, the gate would detach and fall to the floor of the pot removing the obstruction from the entrance funnel and thus allowing animals within the trap to egress. The previous project tested prototype bio-hinge robustness in the recreational Dungeness crab (*Cancer magister*) fishery as well as its degradation in derelict traps. An advantage of the biodegradable hinge mechanism is that it avoids complications involving biofouling since the material degrades away leaving no surface attachment sites for biofouling organisms and is a relatively simple material replacement of an existing product (plastic hinges).

Results from the previous project showed general interest from the fisher participants in the biopolymer technology. However, a common issue centered on the lack of robustness of the experimental bio-hinges in both everyday usage of the traps and even in the transportation of the traps which limited the willingness of fishers to use the technology. Many of the prototype bio-hinges were found to fail too quickly. The general conclusions from testing in both Alaska and Washington State was that the idea was promising but more research was needed on the structural design of the bio-hinge in order to meet the rigors of the Dungeness crab fishery from everyday fishing activity as well as Dungeness crab interaction with the bio-hinge mechanism (Antonelis 2020, Simmons & Heintz 2020).

The original prototype bio-hinges were constructed in-house which likely contributed to their more fragile state. This project took the recommendations from the testing in Alaska and Washington State (i.e. more robustness for added strength with a fuse or weak point for breakage over time) and incorporated them in a commercially designed, molded, and produced bio-hinge.

The primary goal of testing gear in the recreational fishery was to assess bio-hinge durability within the day-to-day handling throughout the fishing season. Catch per unit effort (CPUE) of the test pots versus standard (control) pots was conducted in Alaska but was not analyzed in Washington State since a previous 2019 CPUE Washington State study showed no significant difference in CPUE between traps with bio-hinges and those with standard plastic hinges (Antonelis 2020).

**2. Project Activities & Outcomes**

**Activities**

- *Describe the primary activities conducted during this grant and explain any discrepancies between the activities conducted from those that were proposed.*

Trap loss is common among crustacean fisheries and lost traps, even without bait, can continue to capture and kill both targeted species and bycatch species (Arthur et al. 2014). Depending upon the local environmental conditions and the design and construction material, lost traps can continue to function for years. In the Dungeness crab fishery traps are lost for a number of reasons including surface buoy interaction with vessels and improperly configured gear and the impacts of derelict traps have been well documented (Antonelis et al. 2011, Maselko et al. 2013).

It has been widely recognized that lost traps are a problem for both the target species as well as bycatch species. In the Puget Sound, the 5-year average number of traps lost ranges from 10,782 to 14, 541with loss from the recreational fleet accounting for over 85% of the traps lost annually (NRC/NWSF 2021). In Southeast Alaska, the annual entrapment of Dungeness crabs in derelict traps was estimated at 4.47% of the annual harvest (Maselko et al. 2013). Accordingly, States along the west coast of North American (AK, CA, OR, WA) require traps to be outfitted with biodegradable escape cords or 'rot cords' on the latch that holds the trap door closed. The latch with rot cord is the primary biodegradable component and involves the use of cord such as 100% cotton of certain thread size in order to decompose within three or four months after loss. Once the cord breaks, the intention is that an escape route that was closed off will eventually become open. However, the efficacy of the rot cord has been found to be highly variable and in some cases not effective, particularly when used as part of the door latch mechanism (NRC 2015). Other mechanisms have been proposed to reduce the capture retention rate of animals in derelict Dungeness crab pots such as biodegradable panels and rot cord attachment of the stainless steel escape ring. There is strong interest in a mechanism that 1) releases relatively rapidly (30 -90 days), 2) can be quickly and easily replaced by the fisher while working the traps, 3) is effective at allowing escape of trapped animals when the trap is lost, 4) minimizes the loss of equipment (i.e. stainless steel ring), 5) does not affect crab catch during active fishing, and 6) is relatively inexpensive.

Two types of biohinges, one single piece and one snap together two-piece, were constructed from the biopolymer Polyhydroxyalkanoate (PHA). PHA is a truly biodegradable biopolymer produced in nature that is broken down by microbes in the marine environment with degradation products of water, $CO_2$ and other natural constituents (McDevitt et al. 2017, Hawkins et al. 2021, Pryadko et al. 2021). CAD drawings were professionally produced (see attached photos) and the extrusion company Xcentric Mold & Engineering (https://www.xcentricmold.com/services/injection-molding-service/) was contracted to construct the molds and produce both types of biohinges.

The single piece biohinge was scored along one side to enable installation on the gate and gate entrance. These single piece biohinges were provided to Natural Resources Consulting and Sitka Sound Science Center for testing with recreational Dungeness crab fishers in Washington State and Alaska, respectively. The two-piece snap together biohinge was provided near the end of the project to address installation concerns expressed by participants.

WASHINGTON STATE

Six recreational crab fishers in the Puget Sound tested commercially produced biohinges on their pots during the 2021 summer Dungeness crab season (for the full report please see Appendix1). Pots were delivered to each fisher prior to the beginning of the summer season in early July, and fishers were requested to fill out data collection sheets that included: pot type; date and time deployed; date and time retrieved; water depth; and if bio-hinge failure (degraded to the point of detachment) occurred. In total, 12 pots were used in the study, two per fisher.

Of the 24 bio-hinges, 16 (67%) remained intact throughout the recreational fishing season. Twelve (12; 75%) of the 16 intact bio-hinges showed no change from initial weight prior to deployment in the fishery, while three bio-hinges that soaked for 47.3, 122.5, and 122.7 hours showed a change of 0.69% from initial weight, and the weight of another that soaked for 140.9 hours was reduced by 1.38% (from Table 2 of Antonelis, 2022; see Appendix 1).

Table 2. Status of bio-hinges tested on crab pots in the recreational Dungeness crab fishery July through September 2021.

| **Status of Bio-hinges Tested in Fishery** | **Total** | |
|---|---|---|
| Broke prior to 1st deployment | 1 | 3.3% |
| Broke during transit after 1st deployment/retrieval | 1 | 3.3% |
| Broke during 2nd deployment/retrieval | 2 | 6.7% |
| Broke during 3rd deployment/retrieval | 1 | 3.3% |
| Broke during handling after 3rd deployment/retrieval | 1 | 3.3% |
| Broke during 9th deployment/retrieval | 1 | 3.3% |
| Broke during handling after 10th deployment/retrieval | 1 | 3.3% |
| Remained Intact | 16 | 66.7% |
| Grand Total | 24 | 100% |

Five sites in popular fishing areas within the Puget Sound region were selected to simulate derelict crab pots and test biohinge degradation rates in-situ. One side panel of a common recreational crab pot style was used at each location and each test panel included six bio-hinges used to connect three gates (2 bio-hinges each) to the panel. Each bio-hinge was numbered and weighed prior to attachment. To monitor the status of the soaking biohinges, each site location was visited seven times over a 120 day period; first at 30 days, then approximately every 15 days. During the final site visit the soaking gear was removed from the water and all remaining bio-hinges were dried and weighed.

A total of 30 biohinges were deployed at the five sites across the Puget Sound region from mid-July through November with weights prior to deployment ranging from 1.43 to 1.46 grams (mean: 1.44). Thirteen (43%) of the biohinges were broken and gone by the end of the 60 day soaking period, twenty-one (70%) were broken and gone by the end of the 90 day soaking period, and by the end of the 120-day trials, a total of 23 (77%) biohinges had failed (Table 4 from Antonelis, 2022; see Appendix 1).

Table 4. Count of soaking biohinges by disposition (status) observed at each site location per monitoring period, and degradation rates of those biohinges that remained intact throughout the project period mid-July through November 2021.

| | | Intervals between bio-hinge monitoring (days) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site - Location | Disposition | 30 | 45 | 60 | 75 | 90 | 105 | 120 | Total | Degradation (% Δ) |
| 1 - Bellingham | Broken/Gone | 5 | 1 | | | | | | 6 | |
| 2 - Blaine | Broken/Gone | | 1 | 1 | 2 | | | | 4 | |
| | Intact | | | | | | | 1 | 1 | 18.06 |
| | Intact | | | | | | | 1 | 1 | 16.67 |
| 3 - Port Townsend | Broken/Gone | | 1 | 1 | | | | | 2 | |
| | Intact | | | | | | | 1 | 1 | 13.79 |
| | Intact | | | | | | | 1 | 1 | 16.67 |
| | Intact | | | | | | | 1 | 1 | 15.86 |
| | Intact | | | | | | | 1 | 1 | 13.79 |
| 4 - Cornet Bay | Broken/Gone | | | 1 | 1 | 1 | 1 | 1 | 5 | |
| | Intact | | | | | | | 1 | 1 | 18.75 |
| 5 - Vashon | Broken/Gone | | | 2 | 2 | 2 | | | 6 | |
| Grand Total | | 5 | 3 | 5 | 5 | 3 | 1 | 1 | 30 | |
| % of Bio-hinges Gone during interval | | 16.7 | 10.0 | 16.7 | 16.7 | 10.0 | 3.3 | 3.3 | | |
| Cumulative % of Bio-hinges Gone | | 16.7 | 26.7 | 43.3 | 60.0 | 70.0 | 73.3 | 76.7 | | |

<u>ALASKA</u>

Three recreational fishers were equipped with two modified and two unmodified pots to test how the biohinges functioned during the active fishing season (for the full report please see Appendix 2). The fishers were instructed to handle the pots as they would regular gear and fish the modified pots alongside the unmodified pots. In addition, fishers were given a data sheet for recording fishing conditions, pot performance, and catch. Fishers recorded the date and depth for each deployment along with the number of failed (degraded to the point of detachment) biohinges and the catch of Dungeness crabs and bycatch species. Fishers reported biohinge failure rates ranging from 3.6% to 15.6% (Table 1 from McCarrel and Heintz, 2021; see Appendix 2).

Table 1. Modified pot deployments and failure rates of polymer hinges.

| Fisher | Number of Modified Pots deployed | % Failed Deployments Due to Hinges | Number of Failed Hinges (% of hinges deployed) |
|---|---|---|---|
| 1 | 7 | 0% | 1 (3.6%) |
| 2 | 8 | 0% | 5 (15.6%) |
| 3 | 8 | 0% | 2 (6.3%) |

Catch of Dungeness crabs was compared between modified and unmodified pots by calculating the average catch per hour (CPUE) for each deployment and calculating the mean for each fisher's different pot types. Crab catch was similar in modified crab pots compared to unmodified pots (Figure 3 from McCarrel and Heintz, 2021; see Appendix 2). No significant difference in CPUE (Kruskal-Wallis $\chi$ 2= 0.047, df = 1, p-value = 0.829) was detected between pot types. All three fishers noted that the modified pots fished approximately the same as unmodified pots.

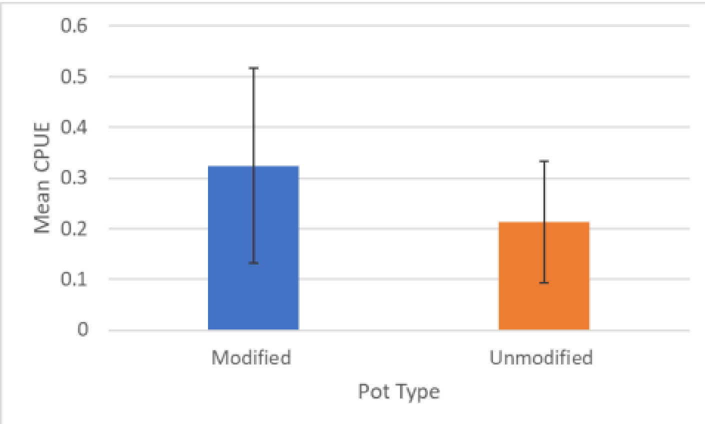


Figure 3: The number of Dungeness crabs caught per hour (CPUE) in both the modified and unmodified pots. Data averaged over 23 different deployments and three recreational fishers testing the efficacy of hinges from September 16th to October 31st, 2021. Error bars depict the stand error interval of the mean.

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**Summary Conclusions**

There remains a general consensus among fishers participating in the project in both Washington State and Alaska that the concept of a biodegradable hinge incorporated into Dungeness crab pots that functions to release the gate mechanism and allow entrapped animals to egress a derelict pot has appeal. However, there remains a concern on the overall robustness of the biohinge. While the incorporation of the biohinge did not affect the catch rate of Dungeness crabs in comparison with unmodified pots, the potential for breakage remains a concern. Fishers in Washington State felt the newer biohinge iteration was more robust, particularly the recent follow-up two piece snap together biohinge (see attached photos) and potentially could solve the issue of breakage during installation or replacement. One fisher in Alaska felt the breakage issue made their use of the biohinge unlikely. The other two fishers in Alaska felt that the idea of contributing to sustainable fishing practices outweighed the fragility of the biohinges. In general fishers in both Alaska and Washington State felt the biohinge a worthy concept and, if not the primary release mechanism for Dungeness pots, then potentially as a redundancy feature to the existing cotton rot cord requirement.

<u>References</u>

Antonelis, K. 2020. Testing effectiveness of bio-hinge escape mechanism on Dungeness crab pots in Puget Sound, Washington. Submitted to the Center for Coastal Resources Management, Virginia Institute of Marine Science, William & Mary, 18 pages.

Antonelis, K. 2022. Testing effectiveness of bio-hinge escape mechanism on Dungeness crab pots in Puget Sound, Washington. Submitted to the Center for Coastal Resources Management, Virginia Institute of Marine Science, William & Mary, 12 pages.

Antonelis, K., D. Huppert, D. Velasquez, J. June. 2011. Dungeness crab mortality due to lost traps and cost-benefit analysis of trap removal in Washington State waters of the Salish Sea. North American Journal of Fisheries Management 31: 880-893.

Hawkins, S., I. Brender, F. de Castro Fonseca, R. Lima da Silva, R. L. Quirino. 2021. Aquaculture Waster: Potential synthesis of Polyhydroxyalkanoates.

Maselko, J., G. Bishop, P. Murphy. 2013. Ghost fishing in the Southeast Alaska commercial

Dungeness crab fishery. North American Journal of Fisheries Management 33: 422-431.

McCarrel, A. and R. Heintz, 2021. Bio-hinge escape mechanism for Dungeness crab traps report summary. Submitted to the Center for Coastal Resources Management, Virginia Institute of Marine Science, William & Mary, 8 pages.

McDevitt, J. P., C. S. Criddle, M. Morse, R. C. Hale, C. B. Bott, and C. M. Rochman. 2017. Environmental Science & Technology 51 (12): 6611-6617. DOI: 10.1021/acs.est.6b05812

Natural Resources Consultants & Northwest Straits Foundation (NRC/NWSF). 2021.DRAFT Derelict shellfish pot gear in Puget Sound: estimating gear loss & effectiveness of impact reduction alternatives. Prepared for NOAA Protected Resources Division. Draft completed Sept. 2021; Final in progress.

Pryadko, A., M. A. Surmeneva,, & R. A. Surmenev. 2021. Review of Hybrid Materials Based on Polyhydroxyalkanoates for Tissue Engineering Applications. *Polymers*, *13*(11), 1738. https://doi.org/10.3390/polym13111738

Simmons, C. and R. Heintz. 2020. Bio-hinge escape mechanism for Dungeness crab traps report summary. Submitted to the Center for Coastal Resources Management, Virginia Institute of Marine Science, William & Mary, 12 pages.

**Outcomes**

- *Describe progress towards achieving the project outcomes as proposed. and briefly explain any discrepancies between your results compared to what was anticipated.*
- *Provide any further information (such as unexpected outcomes) important for understanding project activities and outcome results.*

Economic and ecological impacts associated with the continual capture and mortality of Dungeness crabs as well as bycatch species is a wide spread and well-known concern. The development of a solution that is easy to implement, avoids problems associated with biofouling, and is inexpensive could help mitigate the impacts of lost Dungeness traps.

The proposed project outcome was to produce a biohinge that could be successfully and inexpensively incorporated in the recreational Dungeness crab fishery. Two types of biohinges were commercially produced and, with some further refinement, are at a stage of potential commercial production. At an estimated cost of less than $0.50 per pot, biohinges could serve as the primary derelict pot release mechanism or as a secondary release mechanism used in conjunction with cotton rot cord.

## 3. Lessons Learned

*Describe the key lessons learned from this project, such as the least and most effective conservation practices or notable aspects of the project's methods, monitoring, or results. How could other conservation organizations adapt similar strategies to build upon some of these key lessons about what worked best and what did not?*

The key lessons from this project is to engage with local trusted organizations (Natural Resource Consulting and Sitka Sound Science Center) to help facilitate interaction and engagement with stakeholders. In addition, it is important to recruit fishers to utilize their expertise and gain valuable insight into what is important to the stakeholders. This project was informed by having fishers use the various prototype biohinges in their regular fishing activity and provide feedback on how to improve the prototypes. This resulted in a more robust biohinge as well as a two-piece snap together biohinge to promote ease of installation and replacement.

An additional key lesson is that when developing innovative mechanisms for disabling derelict fishing gear, it is important to plan for taking prototypes to commercial grade production. While prototypes can be constructed in the laboratory, it is very important to work with commercial companies for final product production. Having a commercial grade biohinge provided a significant improvement over the initial prototypes and increased the "willingness to use" component of the project.

## 4. Dissemination

*Briefly identify any dissemination of project results and/or lessons learned to external audiences, such as the public or other conservation organizations.  Specifically outline any management uptake and/or actions resulting from the project and describe the direct impacts of any capacity building activities.*

Project results were presented at talks on innovation and derelict fishing gear and the final report will be sent to the State of Washington Department of Fish and Wildlife who had written a letter of support for the project. The key capacity building activity involved incorporating recommendations from stakeholders in the project for re-design and refinement of the biohinge to address concerns raised in initial testing.

**5. Project Documents**

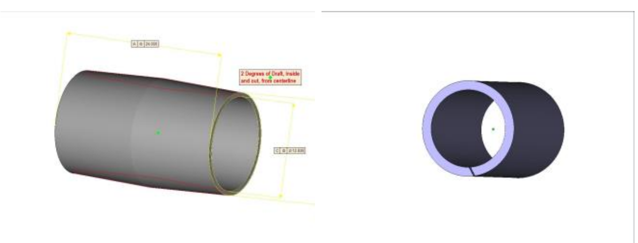
*Include in your final programmatic report, via the Uploads section of this task, the following:*

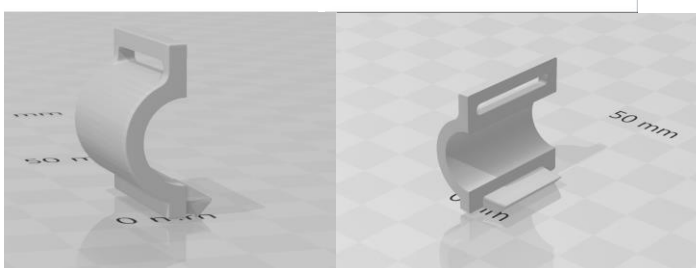
- *2-10 representative photos from the project. Photos need to have a minimum resolution of 300 dpi. For each uploaded photo, provide a photo credit and brief description below;*
- *Report publications, Power Point (or other) presentations, GIS data, brochures, videos, outreach tools, press releases, media coverage;*
- *Any project deliverables per the terms of your grant agreement.*

***POSTING OF FINAL REPORT:*** *This report and attached project documents may be shared by the Foundation and any Funding Source for the Project via their respective websites. In the event that the Recipient intends to claim that its final report or project documents contains material that does not have to be posted on such websites because it is protected from disclosure by statutory or regulatory provisions, the Recipient shall clearly mark all such potentially protected materials as "PROTECTED" and provide an explanation and complete citation to the statutory or regulatory source for such protection.*

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government or the National Fish and Wildlife Foundation and its funding sources. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government, or the National Fish and Wildlife Foundation or its funding sources.

As a result of initial biopolymer research referenced in this report, researchers named as inventors on patents owned by William & Mary may receive royalties on sales of any licensed products. The terms of this arrangement have been reviewed and approved by William and Mary in accordance with its conflict of interest policies. Independent parties were used for the collection and analysis of the primary data in this project.





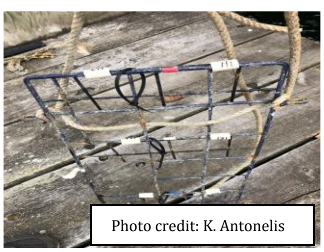
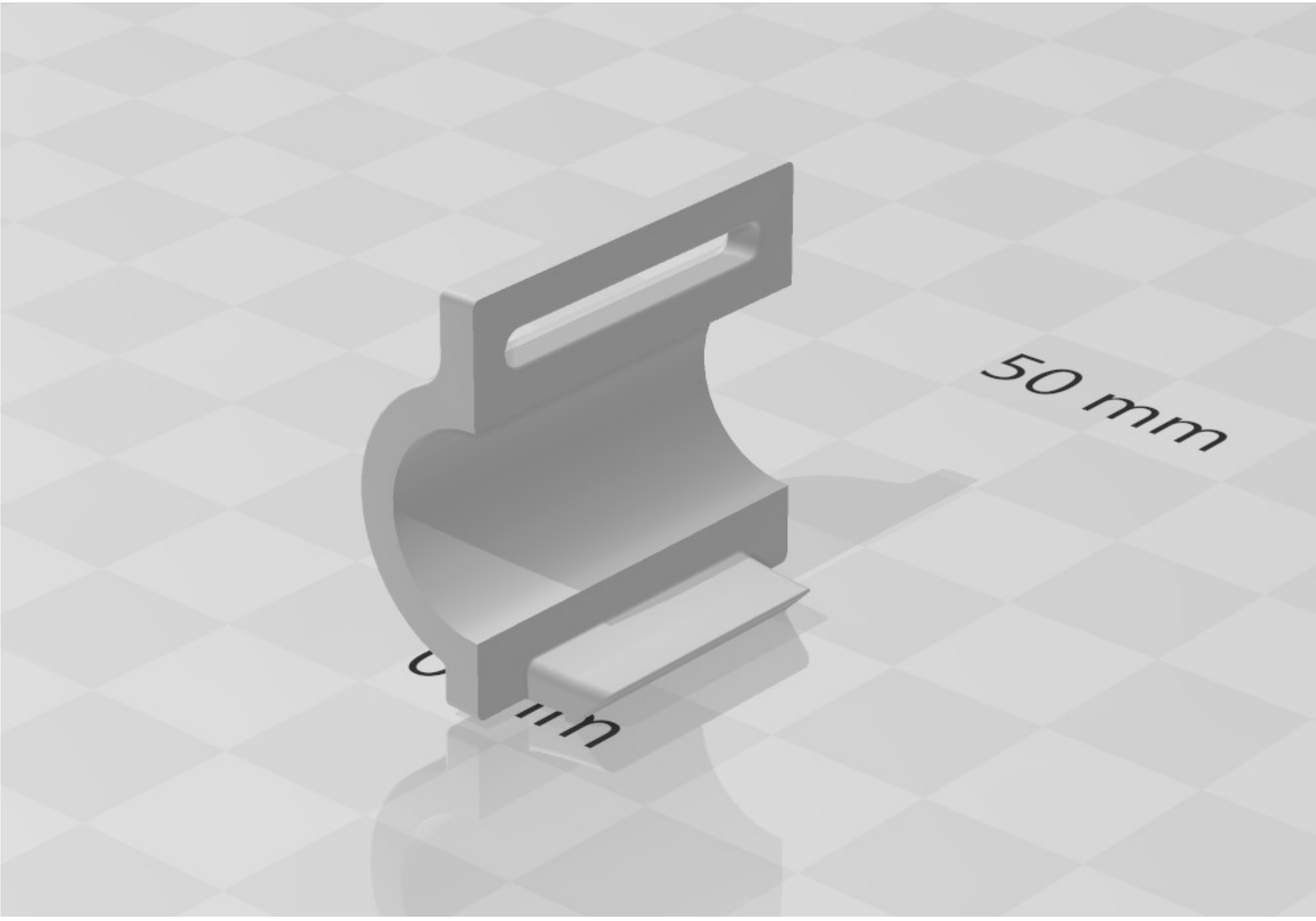



Photo credit: K. Antonelis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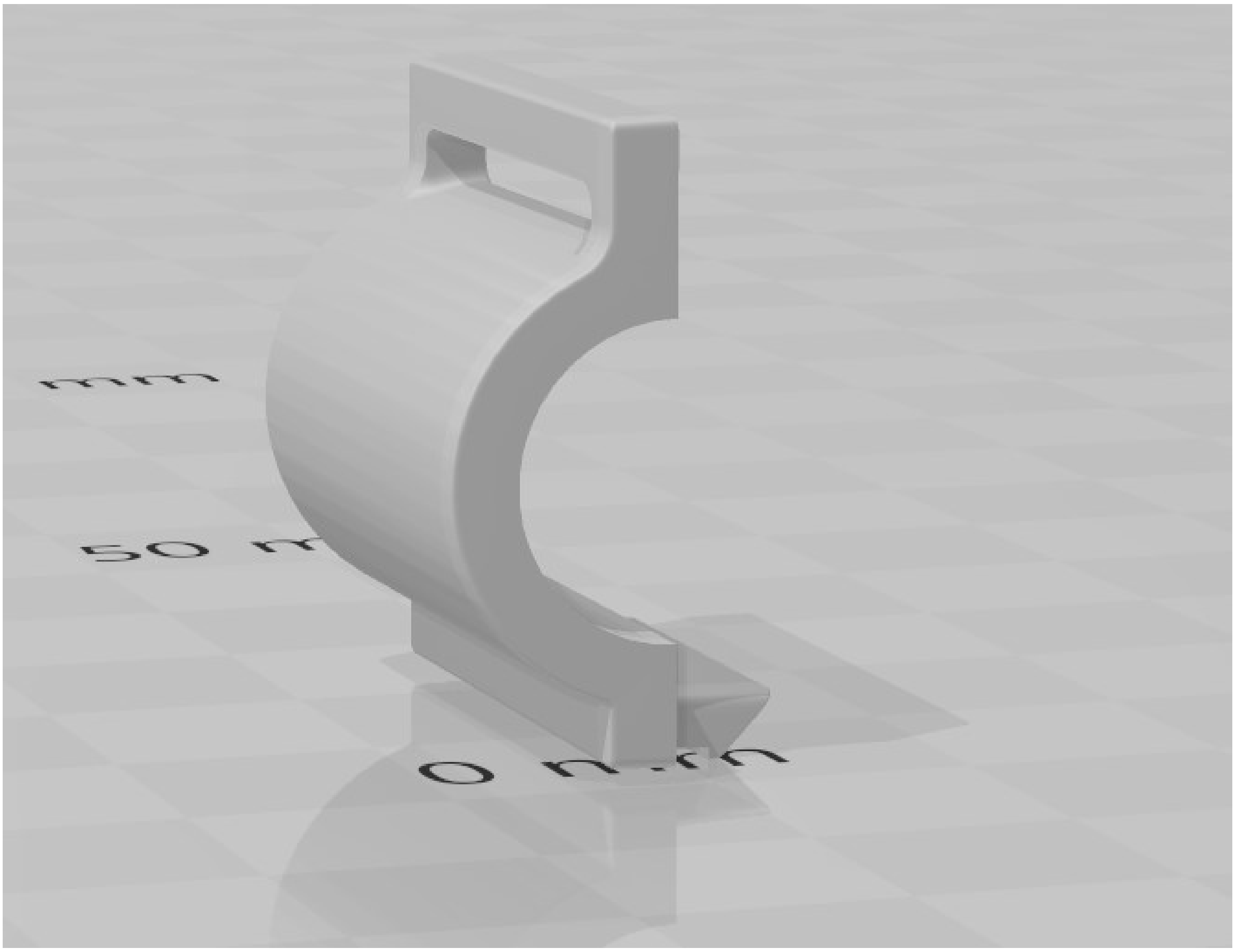
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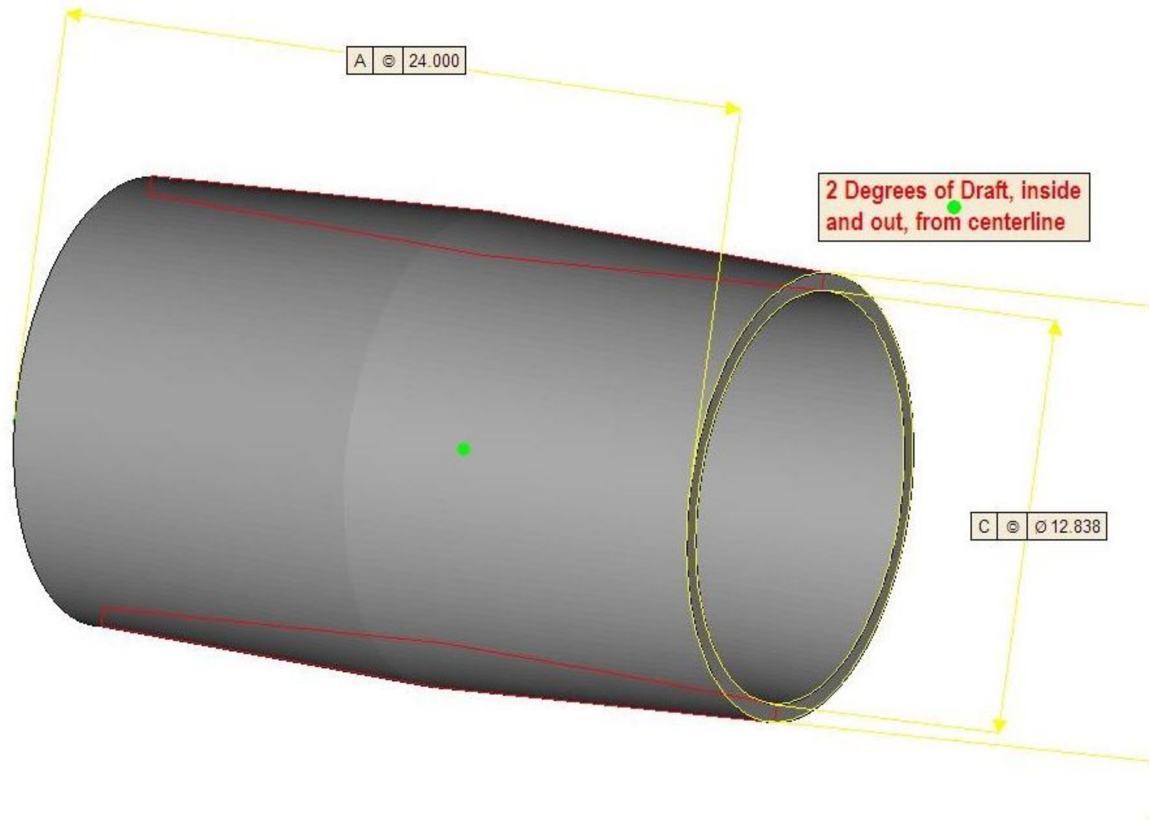

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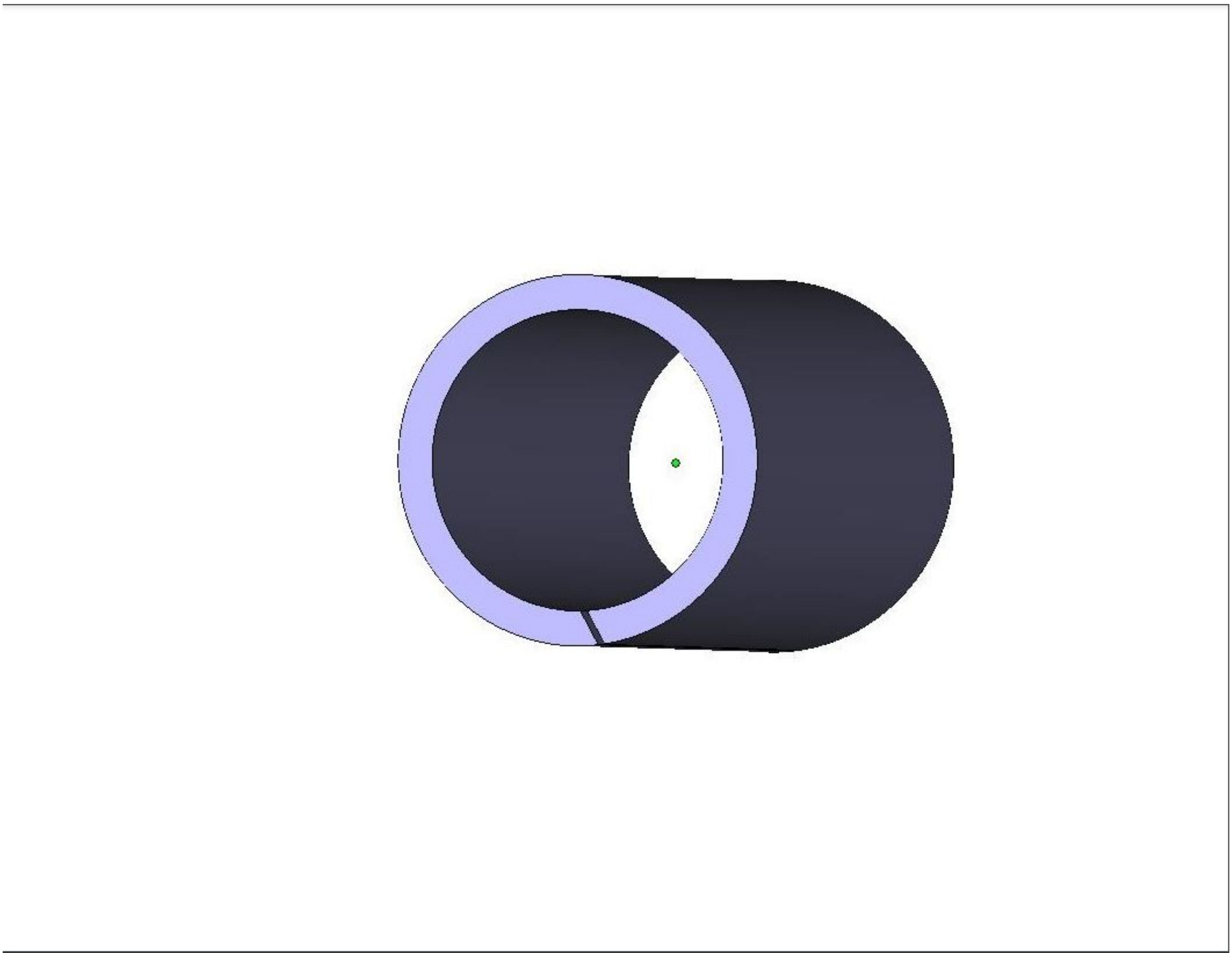

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# TESTING EFFECTIVENESS OF BIO-HINGE ESCAPE MECHANISM ON DUNGENESS CRAB POTS IN PUGET SOUND, WASHINGTON

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## Background and Methods

The Dungeness crab resource in Puget Sound, Washington is co-managed by Washington State (Department of Fish and Wildlife) and 17 Native American Treaty Tribes. The fisheries include three sectors: State Commercial, State Recreational (personal use), and Tribal. The harvestable resources are split 50-50 between the state and tribal fisheries. The resource allocated to the state are then split between the commercial and recreational fisheries. While there is a subsistence/ceremonial component to the tribal fisheries, most landings from the tribal fisheries are commercial in nature; like the state commercial fishery, supplying Dungeness crab to domestic and international markets. There are approximately 250 active state commercial fishing licenses, and approximately 800 active tribal fishers; each sector applies effort control primarily through spatio-temporal closures, quota limits, and pot limits. The recreational fleet regularly exceeds 200,000 license holders, with a 2-pot per license limit, and spatio-temporal closures throughout the Puget Sound based on crab abundance.

Research conducted in Puget Sound estimates that over 12,000 crab pots are lost per year, and that 70% of those are lost from the recreational fleet (Antonelis et al. 2011). Recently updated estimates suggest that since 2011, the 5-year average number of pots lost ranges from 10,782 to 14,541; with gear loss from the recreational fleet accounting for over 85% of the total pots lost annually (NRC/NWSF 2021). To reduce impacts from derelict pots, state and tribal laws require pots to be equipped with biodegradable cotton twine (or other natural fiber, known as “rot cord” or “escape cord”) that once degraded, will provide an egress route for entrapped crab and other organisms to escape through (WAC 220-330-020; WAC 220-340-060). However, studies have shown that rot cord, as required in current regulations, is not always 100% effective in disabling crab pots; particularly when used as part of a door latch mechanism (NRC 2015; Drinkwin 2018). Therefore, strong interest exists in alternatives to the current rot cord regulations; such as the use of thinner cord, escape route modifications, or alternative biodegradable materials. To reduce impacts from derelict crab pots in Puget Sound, the Northwest Straits Foundation (NWSF) and Natural Resources Consultants (NRC) are currently working with Washington Department of Fish and Wildlife (WDFW) and regional treaty tribes to adjust lawful gear requirements. Those suggested changes include: changing maximum thickness of cotton twine from size 120 to size 30, and adjusting language to ensure an unobstructed egress route on the pot wall or topside edge of pot is created upon escape cord degradation (NRC/NWSF, 2021). Additionally, redundancy in pot disabling mechanisms, such as the use of biopolymer technology to replace standard plastics on one-way gate hinges could provide higher probability of escapement, and this study aims to test the efficacy of such materials within the most commonly used recreational crab pots in the region.

In the Puget Sound component of this study, the bio-hinge was tested only on recreational gear for these two primary reasons: (a) recreational gear accounts for the overwhelming majority (85%) of derelict crab pots in Puget Sound, and (b) recreational fishers are limited to two pots per fisher, making modifications to gear a relatively simple task. The efficacy of the bio-hinges in the Puget Sound Dungeness crab recreational fishery were tested by:

- Providing recreational fishers with crab pots equipped with bio-hinges on the one-way entry gates to test the durability of the biopolymer material in the fishery.
- Simulating pot loss in five different locations throughout the Puget Sound to test the bio-hinge degradation rates in-situ.

This is the second iteration of testing this material in Puget Sound, with modified versions of the bio-hinge. The first study was completed in 2019, including the same components but also included soaking gear equipped with bio-hinges in sea water lab tanks.

## Testing Bio-hinge Durability in Recreational Fishery

The primary goal of testing gear in the recreational fishery was to assess bio-hinge durability within the day-to-day handling, transport, deployment, soak, and retrieval of the gear throughout the fishing season. Six recreational crab fishers in the Puget Sound volunteered to test the bio-hinges on their pots during the 2021 summer Dungeness crab season, which generally lasts from early July through early September, with some exceptions. To incentivize this participation, two pots, of premium designs were provided to each of the fishers, each equipped with bio-hinges on one of the three gates, while the remaining two gates were equipped with the standard issued plastic hinges (Figure 1). The catch per unit effort (CPUE) of the test pots versus standard (control) pots were not analyzed, since, as expected the 2019 study showed no significant difference in CPUE between traps with bio-hinges and those with standard plastic hinges. Pots were delivered to each fisher prior to the beginning of the summer season in early July, along with data collection sheets that included: pot type; date and time deployed; date and time retrieved; water depth; and if bio-hinge failure occurred (Figure 2). In total, 12 pots were used in the study, two per fisher.

A total of 24 bio-hinges were tested in the recreational fishery. Of the three total one-way entry gates on the test pots, one was equipped with two bio-hinges holding the gate in place; this would provide ample availability for crab escapement, while also limiting the potential of bio-hinge failure to only one gate rather than three. Bio-hinges were each numbered with permanent marker, and weighed prior to being secured onto the pots. If one bio-hinge failed, it was replaced with the plastic hinge that the pot was originally equipped with, yet any intact bio-hinges were left in place until either failure or study completion. Datasheets were collected at the end of the fishing season, and participating fishers provided feedback regarding their experience with the bio-hinges, particularly regarding durability and practicality of bio-hinge use in the fishery.

## Testing Bio-hinge Degradation in Simulated Lost Pots

Soaking pot gear to simulate derelict crab pots equipped with bio-hinges occurred at five sites in popular fishing areas throughout the Puget Sound region (Figure 3). Sites were chosen based on their geographic distribution, ease of access, and site security. Facility owners and managers were contacted with an explanation of the research plan and goals. Sites included science and research stations, seafood landing facilities, and state and county park facilities (Figure 3 & Table 1). To minimize the footprint of the testing equipment, one side panel of a common recreational crab pot style was used at each location. To avoid the need for dive operations, the pot gear was deployed to the seafloor off the edge of docks and piers with a line connecting the pot gear to the pier structure. On each test panel, a total of six bio-hinges were used to connect three gates (2 bio-hinges each) to the panel. Each bio-hinge was numbered with permanent marker and weighed prior to attachment. A lead weight was attached to the bottom of each panel to ensure the panel remained upright during the extent of the soaking period (Figures 4).

The recreational Dungeness crab fishing season begins each year in early to mid-July, depending on the Marine Area. Bio-hinge equipped pot gear was deployed during the month of July to test deterioration rates under the conditions newly lost gear is most likely subject to; simulating gear loss at the beginning of the recreational season. Following deployment, each site location was visited seven times; first at 30 days, then approximately every 15 days, to monitor the status of the soaking bio-hinges over a 120 day period. During each site visit, project personnel raised the soaking gear to just below the sea-surface so that the bio-hinges were visible, but not removed from the water. Status of each bio-hinge was recorded as either present (intact) or absent (gone). During the fifth and final site visit at each location the soaking gear was removed from the water and all remaining bio-hinges were dried and weighed. The maximum lifespan of each soaking bio-hinge was calculated as the number of days between gear deployment and the monitoring date in which the bio-hinge was observed as absent. For those bio-hinges that remained intact throughout the 120 day soaking period, the final weights were compared to the original recorded weights to determine the deterioration rate as the percent of change from the original weight.

# Results

## Bio-hinge Durability in Recreational Fishery

Fishers participating in the study fished in Marine Area (MA) 8 East in the Everett Flats and Port Susan area; in MA 10 off northern Bainbridge Island; in MA 11 off south and west Vashon Island; and in MA 7 in Birch Bay and the Anacortes area (Figure 3). Fishing effort occurred in water depths ranging from 30 to 90 feet deep (mean: 59.8 feet), and soak time per deployment ranged from 2.0 hours to 31.4 hours (mean: 13.5 hours). Twelve test pots were equipped with a total of 24 bio-hinges. The weights of the bio-hinges prior to deployment were 1.45 g (n=15), 1.44 g (n=7), and 1.43 (n=2) (mean: 1.445) consistently.

Of the 24 bio-hinges, 16 (67%) remained intact throughout the recreational fishing season. Four of those soaked for a total of 10.5 hours; three soaked for 36 hours; two soaked for 39 hours; two soaked for 47.3 hours; three soaked for 122.5 – 122.7 hours, and one soaked for 140.9 hours. The bio-hinges remaining on pots were fished in waters depths ranging from 30 to 84 feet. Twelve (12; 75%) of the 16 intact bio-hinges showed no change from initial weight prior to deployment in the fishery, while three bio-hinges that soaked for 47.3, 122.5, and 122.7 hours, respectively, showed a change of 0.69% from initial weight, and the weight of another that soaked for 140.9 hours was reduced by 1.38%. One bio-hinge broke during gear handling prior to being set in the water; one broke during transit from fishing grounds to port after one soak that lasted five hours in 60 feet of water; one broke during gear handling after ten trips totaling 141.2 soak hours; one bio-hinge broke during gear handling after three trips totaling 92.2 soak hours; and one bio-hinge was found broken upon retrieval from its third deployment, with a total soak time of 36.8 hours (Table 2 & 3).

## Bio-hinge Degradation in Simulated Derelict Crab Pots

A total of 30 bio-hinges were deployed at five sites across the Puget Sound region from mid-July through November. Their weights prior to deployment ranged from 1.43 to 1.46 grams (mean: 1.44). Thirteen (43%) of the bio-hinges were broken and gone by the end of the 60 day soaking period, twenty-one (70%) were broken and gone by the end of the 90 day soaking period, and by the end of the 120-day trials, a total of 23 (77%) bio-hinges had failed. Seven (23%) bio-hinges remained intact throughout the 120-day soaking period; two at Blaine (Site 2), four at Port Townsend (Site 3), and one at Cornet Bay (Site 4). The degradation rate (% Δ) of intact bio-hinges after 120 soaking days in Blaine ranged from 16.67% to 18.06% (mean: 17.36%), the degradation rate of the intact bio-hinges at Port Townsend ranged from 13.79% to 16.67% (mean: 15.03%), and in Cornet Bay the degradation rate of the remaining bio-hinge was 18.75% (Table 4).

Five (16.7%) of the bio-hinges were gone within the first 30 days of the trial; all from the Bellingham site (Table 4). It is not clear why degradation of bio-hinges occurred at this site so quickly compared to others. Tampering was not suspected, as this was likely the most secure of all the sites. We suspect it may be due to the location of the Bellingham site being in a relatively open area, rather than a small bay or harbor like the other sites, and therefore exposed to heavier sea and weather conditions (Figure 1).

Three (10%) of the 30 soaking bio-hinges broke between the 30 and 45 day monitoring periods. These included the final bio-hinge in Bellingham, one in Blaine, and one in Port Townsend (Table 4). Five (16.7%) bio-hinges that were intact at the 45 day monitoring period, were broken/gone at the 60 day site visit; including one at Blaine, one at Port Townsend, one at Cornet Bay, and two at Vashon. Five (16.7%) bio-hinges that remained intact at the 60 day interval were broken at the 75 day interval; two in Blaine, one in Cornet Bay, and two at Vashon. Three (10.0%) broke between the 75 and 90 day interval; one at Cornet Bay and two at Vashon. One (3.3%) bio-hinge at Cornet Bay broke between the 90 and 105 day intervals, and one (3.3%) broke between the 105 and 120 day intervals, both of which were at Cornet Bay. In total, seven (23.3%) bio-hinges were still intact at the end of the 120 day interval; four at Port Townsend, two at Blaine, and one at Cornet Bay (Table 4).

# Comments and Discussion

As was reported after the 2019 bio-hinge experiments, all participants from the recreational fishery and partners allowing use of facilities were very interested in the potential for the bio-polymer to be used as an option for disabling derelict crab pots. While research has shown the cotton escape cord can sometimes fail in disarming derelict pots, depending in the cord thickness, placement, and the style of disabling mechanism, few if any of the participants believed that cotton escape cord needs to be replaced with a new or “better” material. They all, however, agreed that the bio-hinge was worthwhile to investigate as an option for redundancy in pot disabling options. In the 2019 study, it was clear that the bio-hinges available at the time were too brittle to withstand the standard handling of gear during the fishery, and did not deteriorate quickly enough to effectively minimize Dungeness crab mortality in derelict pots.

However, during this 2021 study it was clear that changes to the bio-hinges provided greater strength and capacity to endure the fishery, as 67% of the bio-hinges remained intact after being used in the recreational fishery. Considering the iterative process of engineering and identifying the best suited bio-hinge design, this is certainly a positive sign. Additionally, with 43% of the bio-hinges on the simulated pots broken within 60 days of soaking, and 60% gone within 75 days; results are not far from the ~50 day degradation time targeted as being optimal in reducing crab mortality based on findings from Antonelis et al. (2011). Based on these advancements, we look forward to testing the most updated version of the bio-hinge that includes a two-part snap together design that was recently provided to NRC by VIMS in November 2021.

Two of the six recreational fishers testing gear during the 2021 fishery were those that participated in 2019. Therefore, their feedback included a comparison of the previous designs. In general, there was a more positive assessment of the bio-hinges, as they held their integrity longer and were less prone to breakage during standard transit and gear handling, yet due to the breakage that occurred in some bio-hinges during the season, they were still not robust enough to be considered a viable option. Similar to the assessment of the degradation times in the soaking bio-hinges, it is clear that the design changes had a positive effect, and it appears as though the most recent two-part snap together version could potentially solve this problem.

The upgraded (2021) version of the bio-hinges used in the study in Puget Sound showed that there are still concerns about the strength of the bio-hinge being able to withstand the fishery; however, progress was made in adding to their robustness when compared to the 2019 designs. The variable degradation rates and breakage in the simulated pots during the 2021 study were promising, but still require more time to degrade than the targeted goal of approximately 50 days. These improvements in design, along with the initial review of the more recently modified two-part snap together design suggest that continued adjustments to the bio-hinge design may provide a valuable option for disabling Dungeness crab pots, either as a gate hinge or possibly to hold an escape panel in place.

## References

Antonelis, K., D. Huppert, D. Velasquez, J. June. 2011. Dungeness crab mortality due to lost traps and cost-benefit analysis of trap removal in Washington State waters of the Salish Sea. North American Journal of Fisheries Management 31: 880-893.

Washington Administrative Code (WAC) 220-330-020. Personal-use shellfish gear – Unlawful acts. https://apps.leg.wa.gov/wac/default.aspx?cite=220-330-020

Washington Administrative Code (WAC) 220-340-060. Commercial shellfish pot gear – Escape mechanism required. https://app.leg.wa.gov/WAC/default.aspx?cite=220-340-060

Natural Resources Consultants (NRC). 2015. Determining effectiveness of Dungeness crab escapement in derelict traps commonly used in the Washington waters of the Salish Sea – Final Report. Prepared for the Northwest Straits Foundation. November 2015.

Natural Resources Consultants & Northwest Straits Foundation (NRC/NWSF). 2021.DRAFT Derelict shellfish pot gear in Puget Sound: estimating gear loss & effectiveness of impact reduction alternatives. Prepared for NOAA Protected Resources Division. Draft completed Sept. 2021; Final in progress.

Drinkwin, J, 2018. “Puget Sound Lost Crab Pot Prevention Plan”. Open Science Framework. January 18. doi:10.17605/OSF.IO/PY9RU.

## Tables

Table 1. Simulated derelict crab pot soaking locations and estimated range of water depth at location during the soak times July through November 2021.

| Site | Location | Affiliation/Facility | Facility | Water Depth (ft) |
|---|---|---|---|---|
| 1 | Bellingham | Fathom Seafood | Pier (locked) | 25 - 35 |
| 2 | Blaine | Sound Pacific Seafood | Pier (Private Access) | 10 - 18 |
| 3 | Port Townsend | Port Townsend Marine Science Center | Pier (accessed by kayak) | 22 - 30 |
| 4 | Cornet Bay | Washington State Parks | Dock (locked) | 12 - 20 |
| 5 | Tramp Harbor, Vashon | Vashon Parks Fishing Dock | Pier (accessed by kayak) | 12 - 20 |

Table 2. Status of bio-hinges tested on crab pots in the recreational Dungeness crab fishery July through September 2021.

| Status of Bio-hinges Tested in Fishery | Total | |
|---|---|---|
| Broke prior to 1st deployment | 1 | 3.3% |
| Broke during transit after 1st deployment/retrieval | 1 | 3.3% |
| Broke during 2nd deployment/retrieval | 2 | 6.7% |
| Broke during 3rd deployment/retrieval | 1 | 3.3% |
| Broke during handling after 3rd deployment/retrieval | 1 | 3.3% |
| Broke during 9th deployment/retrieval | 1 | 3.3% |
| Broke during handling after 10th deployment/retrieval | 1 | 3.3% |
| Remained Intact | 16 | 66.7% |
| Grand Total | 24 | 100% |

Table 3. Count of bio-hinges by final disposition (status) with associated total number of hours soaked and average depth of soak during Puget Sound recreational Dungeness crab fishery July through September 2021.

| Status | Number of bio-hinges | Total Soak Time (hrs) | Avg. Depth (ft) |
|---|---|---|---|
| Broken/Gone | 1 | 0 | 0 |
| Broken/Gone | 1 | 5.0 | 60 |
| Broken/Gone | 2 | 29.0 | 35 |
| Broken/Gone | 1 | 36.8 | 51.3 |
| Broken/Gone | 1 | 92.2 | 67.3 |
| Broken/Gone | 1 | 122.7 | 70.4 |
| Broken/Gone | 1 | 141.2 | 71.3 |
| Intact | 2 | 10.5 | 63.3 |
| Intact | 2 | 10.5 | 66.7 |
| Intact | 1 | 36.0 | 69.8 |
| Intact | 2 | 36.0 | 73.0 |
| Intact | 2 | 39 | 41.0 |
| Intact | 2 | 47.3 | 43.8 |
| Intact | 1 | 47.3 | 55.0 |
| Intact | 1 | 122.5 | 65.5 |
| Intact | 2 | 122.7 | 72.5 |
| Intact | 1 | 140.9 | 71.9 |
| Grand Total | 24 | | |

Table 4. Count of soaking bio-hinges by disposition (status) observed at each site location per monitoring period, and degradation rates of those bio-hinges that remained intact throughout the project period mid-July through November 2021.

| | | Intervals between bio-hinge monitoring (days) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site - Location | Disposition | 30 | 45 | 60 | 75 | 90 | 105 | 120 | Total | Degradation (% Δ) |
| 1 - Bellingham | Broken/Gone | 5 | 1 | | | | | | 6 | |
| 2 - Blaine | Broken/Gone | | 1 | 1 | 2 | | | | 4 | |
| | Intact | | | | | | | 1 | 1 | 18.06 |
| | Intact | | | | | | | 1 | 1 | 16.67 |
| 3 - Port Townsend | Broken/Gone | | 1 | 1 | | | | | 2 | |
| | Intact | | | | | | | 1 | 1 | 13.79 |
| | Intact | | | | | | | 1 | 1 | 16.67 |
| | Intact | | | | | | | 1 | 1 | 15.86 |
| | Intact | | | | | | | 1 | 1 | 13.79 |
| 4 - Cornet Bay | Broken/Gone | | | 1 | 1 | 1 | 1 | 1 | 5 | |
| | Intact | | | | | | | 1 | 1 | 18.75 |
| 5 - Vashon | Broken/Gone | | | 2 | 2 | 2 | | | 6 | |
| Grand Total | | 5 | 3 | 5 | 5 | 3 | 1 | 1 | 30 | |
| % of Bio-hinges Gone during interval | | 16.7 | 10.0 | 16.7 | 16.7 | 10.0 | 3.3 | 3.3 | | |
| Cumulative % of Bio-hinges Gone | | 16.7 | 26.7 | 43.3 | 60.0 | 70.0 | 73.3 | 76.7 | | |

# Figures

Figure 1. Octagonal, three gated-entry, Danielson brand Dungeness crab pots (top) equipped with bio-hinges.

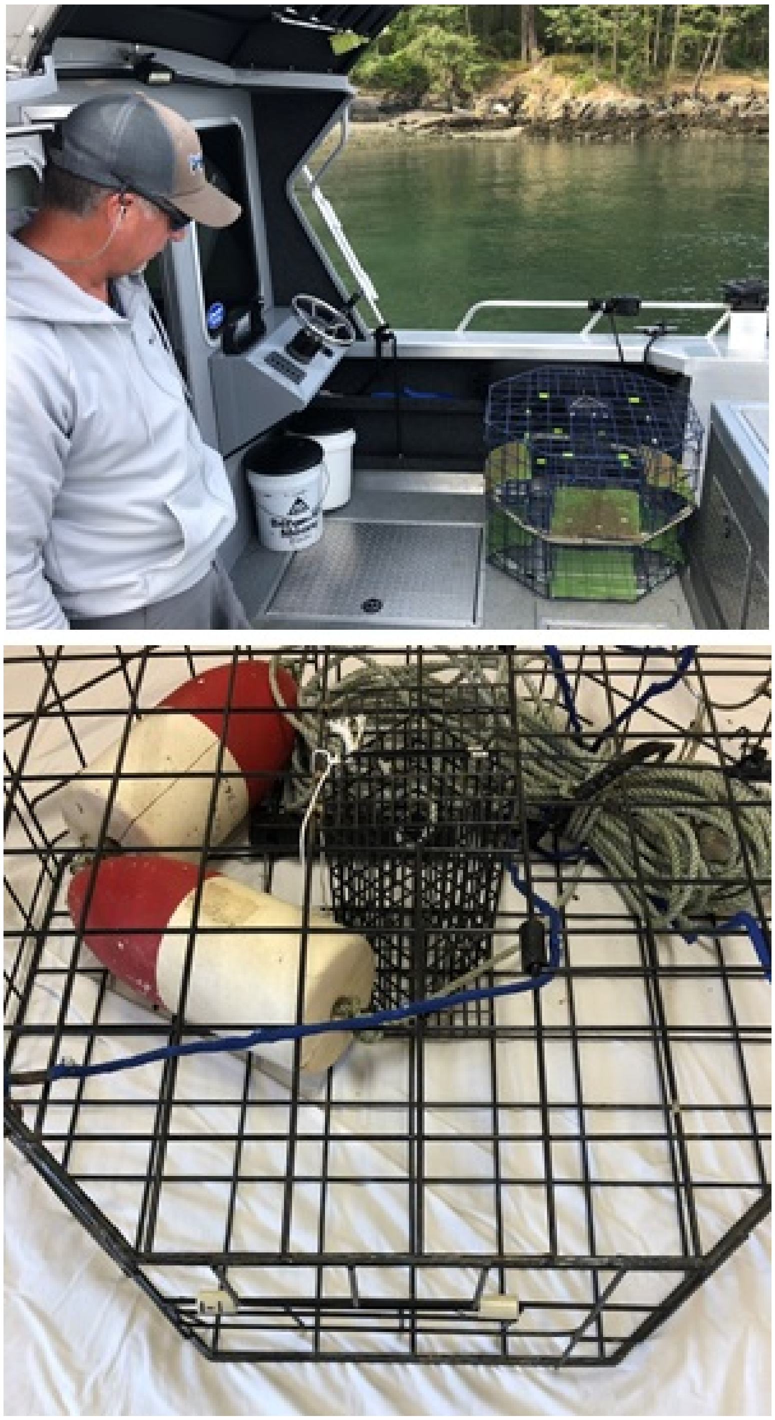

Figure 2. Datasheet provided to recreational fishers participating in bio-hinge testing study in Puget Sound 2021 summer fishery.

VIMS and NRC
Name:__________

Biohinge Study in Recreational Dungeness crab Fishery

Puget Sound, WA -- 2021

| POT (1 OR 2) | DATE DEPLOYED | TIME DEPLOYED | DATE REMOVED | TIME REMOVED | WATER DEPTH (ft) | BIOHINGE FAILURE? (Y/N) | WHICH BROKE (1 OR 2) | NOTES |
|---|---|---|---|---|---|---|---|---|
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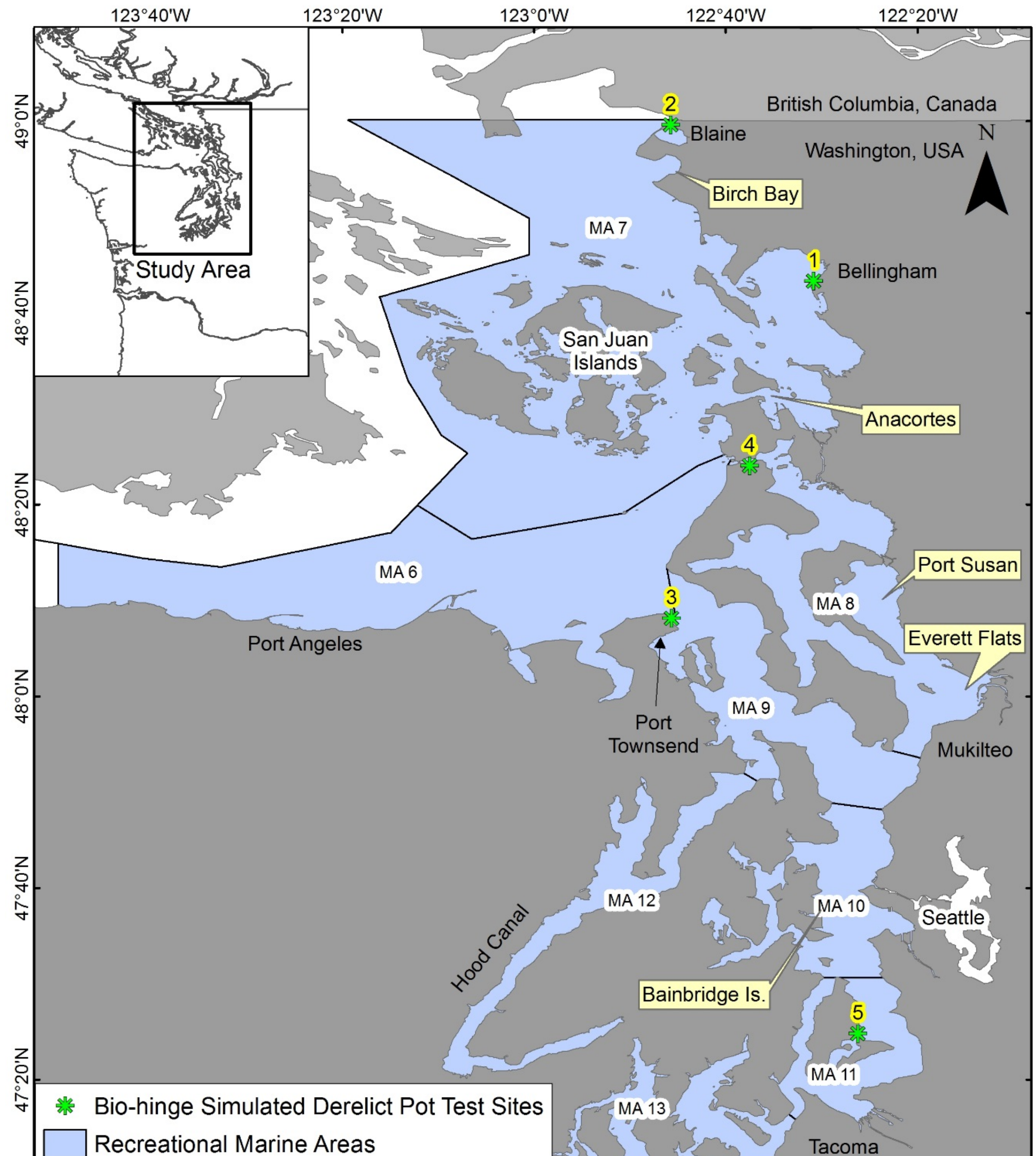
Figure 3. Map of Puget Sound with simulated derelict crab pot soak testing sites, marine recreational fishing area boundaries, and general fishing area names where bio-hinges were used in by participating recreational fishers.

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| 4 | Cornet Bay | Washington State Parks | Dock | 12-20 |
| 5 | Tramp Harbor, Vashon | Vashon Parks | Pier | 12-20 |

Figure 4. Image of pot panel prior to deployment, equipped with 6 bio-hinges, loosely placed zipties to prevent debris, and a lead weight to keep the soaking gear in place.

## Bio-Hinge Escape Mechanism for Dungeness Crab Traps Report Summary

**Alex McCarrel and Ron Heintz**

**Sitka Sound Science Center**

**Abstract:**

Lost crab pots can continue fishing resulting in the overexploitation of crab populations because the so-called rot cord escape mechanisms may fail, allowing pots to fish for a prolonged period. We evaluated the efficacy of biodegradable hinges as a potential alternative to the biodegradable rot cord method. We conducted a field application to test the practicality of hinges. Our results show that the catch per hour of Dungeness crabs (*Cancer magister*) for modified pots was not significantly different compared to unmodified crab pots. Deployment failure rates due to hinge loss for the field application were 0% with a small number of reported hinge failures. Watermen concluded that hinges were fragile and the time to replace hinges was high, but they ultimately recommended using the hinges in the future to reduce the impacts of derelict gear.

**Introduction:**

Trap loss is a common occurrence across crustacean fisheries that often results in derelict gear that continues to capture and kill both targeted and bycatch species (Arthur et al. 2014). In Southeast Alaska alone, the annual entrapment of Dungeness crabs (*Cancer magister*) in derelict traps, a commercially targeted species, was estimated to be at 4.47% of the annual harvest (Maselko et al. 2013). Traps along the west coast are outfitted with a biodegradable rot cord that, once degraded, allows organisms a route to escape to help lessen the impacts of derelict gear on crustaceans. However, the efficacy of the biodegradable rot cord has been highly variable and, in some cases, not effective (NRC 2015). To address this variability, the Sitka Sound Science Center was contracted by the Virginia Institute of Marine Science (VIMS) to assess the use of biopolymer technology as a mechanism for Dungeness crab traps. The concept is to replace the stainless-steel hinges on the gates that allow crabs to enter the pots with a biopolymer that will degrade over time. Then if the gear outfitted with the biopolymer hinges becomes derelict the hinges will degrade through time and provide egress for captured organisms.

The goal of this study was to examine the utility of biodegradable polymer rings as hinges on crab pots in Alaskan waters, this being the second iteration of the project with VIMS providing new versions of the biodegradable polymer rings for 2021. To examine the utility of the new biodegradable polymer rings, we provided three watermen with test pots and asked them to compare the utility of pots modified with the polymer rings with the performance of unmodified pots typically used by Alaskan sport crabbers. This report details the summary and findings for these this approach. The raw data are available and will be submitted as a separate attachment.

**Methods:**

**Study location:** The field component of this project was conducted in waters near Sitka, Alaska. Sea water temperatures in Sitka Sound range from 5° C to 10° C (NCEI 2020). Sitka Sound supports a variety of commercial, recreational, and subsistence fisheries and is an ideal location to study the efficacy of these hinges in colder, more Northern waters. The watermen conducted their crabbing using their usual methodologies.

**Field Application Assessment:**

Three recreational watermen in Sitka, Alaska were given both two modified and two unmodified pots to test how the hinges actively fished (Figure 1). For each of the modified pots, the left and right-side gates were outfitted with the 2021 version biodegradable hinges (Figure 1b). The pots were purchased at a local fishing supply store. They differ in the design of the gate from pots used in previous studies (Figure 2). These new pots were selected because the modified gates more closely resembled the unmodified gates than in our previous study. Previously, the watermen had complained that the gate modification reduced trap efficiency.

The watermen were instructed to treat the pots as they would any gear and let the pots soak for a variety of hours, depths, and locations, but to always fish the modified pots alongside the unmodified pots. Watermen were allowed to simultaneously crab with their personal gear as well. In addition, watermen were given a data sheet for recording fishing conditions, pot performance, and catch. Watermen recorded the date and depth for each deployment along with the number of failed rings and the catch of Dungeness crabs and other marine species. Catch of Dungeness crabs was compared between modified and unmodified pots by calculating the average catch per hour (CPUE) for each deployment and finding the mean for each waterman's different pot types. CPUEs were compared between pot types using a non-parametric Kruskal-Wallis test by rank.

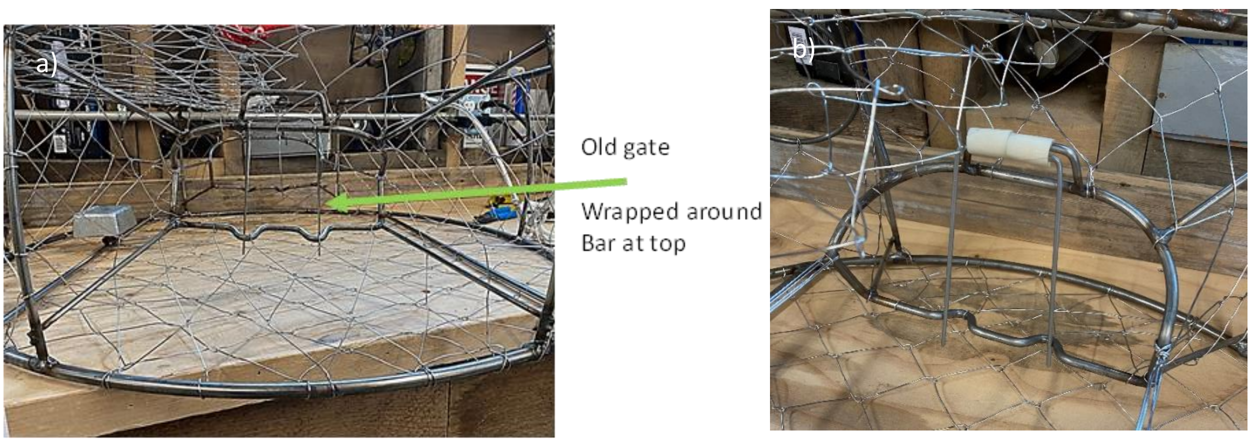


Figure 1. Images of a) unmodified crab pot gate and b) modified crab pot with similar "U" shaped crab pot gate with new polymer hinge attachment points.

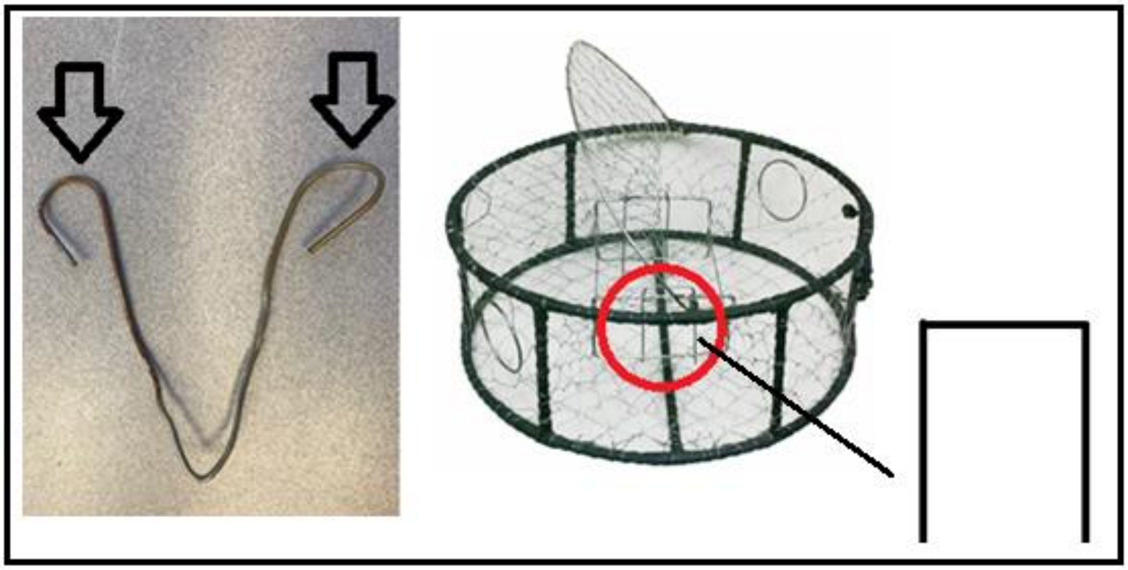

Figure 2. Pot used in previous experiment with inset showing the modified gate used to replace the standard gate.

**Results:**

**Field Application Assessment:**

Three watermen deployed pairs of modified and unmodified pots between September 16th and October 31st, 2021. Each waterman was given two modified and two unmodified pots and was requested to fish them in pairs. Watermen varied in the amount of fishing effort expended (Table 1) and the completeness of their reporting. All three watermen maintained complete records of hinge condition upon retrieval and reported hinge failure rates of 0% (Table 1). Watermen 2 reported the highest hinge failure rate of 15.6% compared to the other two participants, with Watermen 1 reporting the lowest hinge failure rate of 3.6% (Table 1). Comments from the watermen that describe their observations of the effectiveness and ease of use of the modified traps are attached in Appendix A.

Crab catch was similar in modified crab pots compared to unmodified pots (Table 2; Figure 3). A Krukal-Wallis test by rank detected no significant difference in CPUE (Kruskal-Wallis $\chi^2$= 0.047, df = 1, p-value = 0.829) between pot types. The average (+/- standard error) CPUE of the modified pots was 0.324 +/- 0.192 CPUE Dungeness crabs per hour compared to 0.213 +/- 0.120 CPUE for Dungeness crabs per hour for the unmodified pots. Waterman 1 reported an average 0.062 crabs per hour in the modified pots versus 0.112 crabs per hour in the unmodified pots. Waterman 2 reported an average catch of 0.024 Dungeness crabs per hour in the modified pots versus 0.016 crabs per hour in the unmodified pots. Waterman 3 had the highest CPUE out of the three participants for both modified and unmodified crab pots, reporting an average catch of 0.853 Dungeness crabs per hour in the modified pots versus 0.499 Dungeness crabs per hour in the unmodified pots. Waterman 3 also reported the number of Dungeness crabs caught versus the number of legal crabs kept.

All three watermen noted that the modified pots fished approximately the same as unmodified pots. The watermen also commented on the fragility of the hinges and the increased time it took to replace damaged or lost hinges. A moderate number of hinges broke upon handling and fishing. Waterman 3 believed that the modified hinge design was negatively influencing catch rates, noting a lack of side-side strength in the polymer hinges. The full comments from watermen are provided in Appendix A.

Table 1. Modified pot deployments and failure rates of polymer hinges.

| Waterman | Number Modified Pots Deployments | % Failed Deployments Due to Hinges | Number Failed Hinges (% of hinges deployed) |
|---|---|---|---|
| 1 | 7 | 0% | 1 (3.6%) |
| 2 | 8 | 0% | 5 (15.6%) |
| 3 | 8 | 0% | 2 (6.3%) |

Table 2. Raw catch and Catch per Hour (CPUE) of Dungeness crab in modified and unmodified pots.

| | | | Dungeness Catch (CPUE) | |
|---|---|---|---|---|
| Waterman | Average depth fished | Median soak time | Modified | Unmodified |
| 1 | 25 m | 135 h | 7 (0.06) | 14 (0.11) |
| 2 | 19 m | 189 h | 20 (0.024) | 23 (0.016) |
| 3 | 23 m | 5 h | 24 (0.85) | 16 (0.50) |

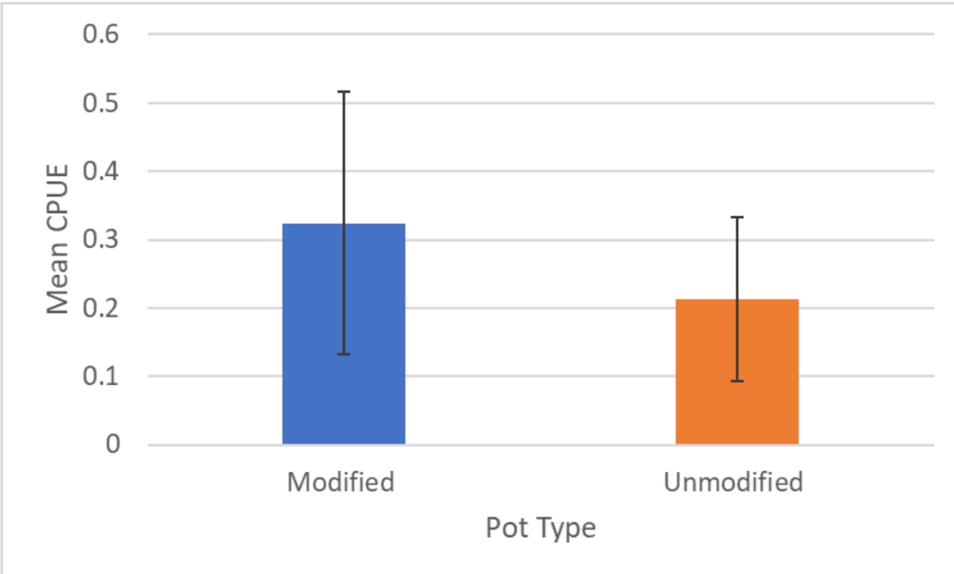


Figure 3: The number of Dungeness crabs caught per hour (CPUE) in both the modified and unmodified pots. Data averaged over 23 different deployments and three recreational watermen testing the efficacy of hinges from September 16th to October 31st, 2021. Error bars depict the stand error interval of the mean.

**Discussion:**

If derelict crab pots do not provide an opportunity for egress, then they will continue fishing. Current technology that relies on the degradation of a cotton line to allow organisms to eventually egress, can fail for a variety of reasons. While biopolymer hinges offer an attractive alternative and catch rates were not significantly different between modified and unmodified crab pots, in practice their continued handling sensitivity make them less appealing to some Alaskan watermen. Quantitative and qualitative results show that these hinges are often fragile with no significant difference in Dungeness crab yields in modified pots, yet Watermen 1 and 2 both stated that the idea of sustainable crabbing overcomes the downfalls of the fragility of the hinges and the increased time for pot deployment. Comments from Watermen 3 regarding the hinges demonstrate that it is unlikely they would be willing to adopt the technology, unlike what was stated by Watermen 1 and 2.

The brittleness of the biopolymer presented minor issues to the watermen. The hinges were found to occasionally break by watermen as they attempted to replace the lost hinges, though 0% of the watermen reported a complete deployment failure due to the hinges. The ease with which the hinges broke while replacing meant that the time spent preparing pots for fishing was greater for the modified pots than for those outfitted with rot-cotton.

Future work should include hinges with increased side-to-side strength. One waterman reported observing when a crab was in the gate part way with the hinges up, the crab would dislodge the hinges more easily by moving the gate side-to-side. Two watermen reported their hesitancy with using the modified crab pot hinges due to their worry of a lack of replacement hinges.

Overall, the biodegradable hinges as a potential alternative to the current mode (biodegradable rot cord cotton) is a somewhat useful application of the technology in Southeast Alaska, in its current form. More research needs to be conducted on how modified hinge strength influences catch rates and how to increase the products ease of use and accessibility for the fishing community, especially for the commercial crabbing industry where most watermen reported opinions of unsuitability for use in commercial crabbing.

## Appendix A: Comments from Watermen

"Liked the product, liked the idea of replacing the cotton twine, a creative alternative that hopefully will get improved.
Yes, [I] will keep fishing them until I run out- had crab in both modified and unmodified pots. The hinges would be better for shorter term soaks because there is more play in the door, a bigger gap that crabs can get back out of. [The] commercial crabbing industry might be a better fit because they have shorter soaking periods.
Only had one hinge break! Easy to replace and to keep crabbing. I wonder if the bigger mature crabs are pinching the hinges to break them, [I] witnessed this when I pulled up the pot with a broken hinge and there were a lot of large mature crabs in the pot" -*Recreational fisherman*

"Really cool [project]. Some of the hinges broke, some broke by [waterman] and some underwater. Really satisfied with the project, liked the idea of replacing the ropes, afraid the hinges would get stuck open or closed but that didn't happen. Seems like the normal crab pots caught a lot more smaller Dungies compared to the modified hinges. Own personal crab pots fished the same as the SSSC crab pots- didn't notice much of a difference.
Would use both methods [modified and unmodified crab pots], the only thing [I] was leery about was not having enough replacement hinges to keep crabbing with the modified hinges.
Would highly recommend to family and friends. The only thing to be worried about is that the hinges are so small and commercial fishermen are in a rush, might be hard and a lot might be broken-rough seas and pot throwing. 65%-75% sure commercial fishermen would like them. Super easy, only broke one hinge replacing them, especially once you get the feel for them."- *Recreational fisherman*

"A great idea, but I think that the trigger release mechanism is not going to work. It has too much of a tendency to [be] loose and hinge and crabs would get stuck in it. Might even be more effective to tie cotton on each door hinge instead of the plastic hinges.
Won't continue to use the hinges.
No, would not recommend [the hinges]. The hinges didn't have any side-to-side strength. When a crab was in the door part way with a hinge up, the crab would dislodge the hinges more easily. [I] changed the tie up point to the line for the crab pots (like how they do for commercial pots) but that is right where the trigger is. It would be pressure on the triggers. [I] changed it over to the side but they didn't catch any crab.
Wasn't hard to replace the hinges. It took time, especially when you are trying to be fast when moving and setting the gear. Don't want to fiddle with hinges while you are trying to change bait and move pots.
When using own crab pots, didn't catch enough crab to give a good comparison. [Waterman] had a little light weight square crab pot, but it didn't catch anything. All the crab were caught in the SSSC pots. The SSSC pots seemed to fish just fine-stainless steel was not an issue."- *Recreational fisherman*

Literature Cited:

Arthur, C., A. E. Sutton-Grier, P. Murphy, H. Bamford. 2014. Out of sight but not out of mind: Harmful effects of derelict traps in selected U.S. coastal waters. Marine Pollution Bulletin 86: (1-2): 19-28.

Maselko, J., G. Bishop, P. Murphy. 2013. Ghost fishing in the Southeast Alaska commercial Dungeness crab fishery. North American Journal of Fisheries Management 33: 422-431.

NCEI. 2020. Water Temperature Table of the Alaska Coast. National Oceanic and Atmospheric Administration. https://www.nodc.noaa.gov/dsdt/cwtg/alaska.html.

NRC. 2015. Determining effectiveness of Dungeness crab escapement in derelict traps commonly used in the Washington waters of the Salish Sea. Natural Resources Consultants, Inc. Final Report to Northwest Straits Foundation. Seattle, Washington.