North Pacific Coast Marine Resources Committee (NPC MRC)
REQUEST FOR PROPOSALS 2022-2023 Funding Round

1. Name of the project:
Remotely Operated Vehicle (ROV) testing and Artificial Intelligence (AI) analyses: a pilot study to spark a long-term Outer Coast monitoring program

2. Lead organization and Contact:
Dr. Zachary Randell, Special Projects Volunteer, Seattle Aquarium
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3. Start and end dates for the project:
March 1st, 2022 — December 31st, 2022

4. Deliverables:
1) We will develop protocols for operating a small ROV just off the bottom in relatively shallow (5-40m) depths, including along urchin barren, understory algae, and kelp canopy forming locations.
2) Trained machine learning algorithms will be made public that classify (a) percent-coverage of colonial, sessile, and aggregated benthic taxa, and (b) abundances of conspicuous species such as sea urchins, sea stars, certain macroalgae, demersal and some (within transect) midwater fishes.
3) Randell will create text and video tutorials (the latter of which will be posted to YouTube) so that other researchers can incorporate these AI methods—either via using the trained algorithms we propose to generate, *or* through training new algorithms from their own imagery.
4) We will work with Bill Monette in Neah Bay to host a Schools Without Walls event about ROV surveys of the benthos. We will also work with Camden Jones at Neah Bay High School and Alice Ryan at the Quileute Tribal School to develop lectures about kelp-forest ecology in a changing climate. We propose to develop ROV-based field trips for these classrooms, and in collaboration with OCNMS and Alice we will interface our project with the MATE ROV competition.
5) We will regularly update and make presentations the Intergovernmental Policy Council, Sanctuary Advisory Council, and Washington Coastal Marine Advisory Committee. Likewise, we will regularly update and make a final report to the North Pacific Coast Marine Resources Committee.

5. Project Staff:
Principal Investigator (PI): Dr. Zachary Randell, Seattle Aquarium (*CV attached*)
Dr. Shawn Larson, Seattle Aquarium (*CV attached*)

6. Partners: (alphabetically listed) *Letters of Support attached at the end of this document*
Dr. Henry Carson, Washington Department of Fish and Wildlife (WDFW)
Dr. Blake Feist, NOAA National Marine Fisheries Service (NMFS)
Nicole Harris, Olympic Coast National Marine Sanctuary (OCNMS)
William Jasper, Makah Fisheries Management (MFM)
Camden Jones, Neah Bay High School (NBHS), Cape Flattery School District (CFSD)
Bill Monette, Makah Tribe
Robert Pacunski, WDFW
Alice Ryan, Quileute Tribal School (QTS)
Dr. Jodie Toft, Puget Sound Restoration Fund (PSRF)
Jenny Waddell, OCNMS
Katie Wrubel, OCNMS

7. Geographic Area

We propose to conduct tests of a Remotely Operated Vehicle (ROV) in the nearshore subtidal (5-40m depth) south of Cape Flattery and north of Destruction Island. Preliminary tests in the spring will take place just south of Cape Flattery, e.g., around Tatoosh Island. Full ROV deployment will culminate in the summer by flying the ROV above and around the OCNMS subtidal monitoring sites offshore of Koitlah Point, Tatoosh Island, Cape Alava, Cape Johnson, and Destruction Island.

8. Permits

An Office of National Marine Sanctuaries Permit will be required to carry out this work, and we are coordinating with Katie Wrubel, the permit coordinator for OCNMS.

9. Project Narrative: (a) Abstract

A central challenge to coastal management and conservation is the inability to survey the seafloor across a broad spatial extent. Scientific SCUBA divers are readily able to survey relatively small areas (on the order of 10-100s of meters), but as kelp forests exhibit high spatial variability and rich spatiotemporal dynamics, inference from a few locations cannot easily be generalized out to broader scales. Remotely operated vehicles (ROVs) have the potential to capture data across a comparatively larger spatial area, but thus far their size and expense has mostly restricted ROV usage to exploring deeper locations unsuitable for divers. However, technological advancement has produced ROV models that are small, affordable, capture high-resolution imagery, and are deployable from small vessels.

In conjunction with Tribal, state, federal, and non-profit partners, we propose to bring the next generation of subtidal monitoring technology and analytical techniques—ROVs and Artificial Intelligence (AI)—into kelp forests and communities along the Outer Coast. Specifically, we propose to iteratively test and modify standardized ROV survey protocols to obtain high-resolution video of the benthos in relatively shallow waters (5-40m) characterized by urchin barrens, understory algae, and canopy-forming beds of Bull (*Nerocystis luetkeana*) and Giant (*Macrocystis pyrifera*) kelp. As it would be labor intensive to have a human review all the ROV imagery, we will train existing AI algorithms to classify percent-coverage from photo stills (CoralNet [1]) and identify and track individuals from video (VIAME [2]). *We envision this study as a first step towards a long-term subtidal monitoring program. We therefore propose to work with communities in what we hope will also be a long-term partnership.* We propose to work with Bill Monette in Neah Bay to host a Schools Without Walls event focused around ROV survey methods. We also propose to work with Neah Bay High School and the Quileute Tribal School to develop kelp-forest lecture content and ROV-based field trips so that students can experience the seafloor right outside of their classrooms.

(b) Background

Kelp forests along the western strait of Juan de Fuca and Outer Coast of Washington provide habitat and refuge to numerous species of significant management concern, including state, federally, and internationally listed threatened and endangered species such as the sunflower sea star (*Pycnopodia helianthoides*), yelloweye and bocaccio rockfish (*Sebastes ruberrimus* and *Sebastes paucispinis* respectively), and several stocks of salmon [3]. The status of the critically endangered Pinto Abalone (*Haliotis kamtschatkana*) is virtually unknown along the Olympic Coast [4]. Furthermore, benthic habitat adjacent to kelp forests supports culturally important species such as clams, sea cucumbers, and Dungeness crabs (*Metacarcinus magister*) [5], yet these locations—along with kelp forests—are increasingly subject to low oxygen or hypoxia related events [6]. Understanding the distribution, functioning, and overall health of Washington's coastal kelp forests, the adjacent habitat, and all associated species is vital for supporting regional management and conservation, particularly within the context of changing ocean conditions [7].

A recent global analysis documented an overall decline at local spatial scales in kelp forest coverage, though the precise driving mechanisms are anticipated to vary and are at times uncertain [8]. What is clear, however, is that the combination of climate change associated anomalous warm-water, marine disease, and hypoxia events can wreak havoc along coastlines. Coastal managers watched with unease as the fallout from the 2013-2015 anomalous warm-water event (i.e., “The Blob”) and subsequent El Niño phase unfolded along the Pacific northeast: in northern California alone, more than 90% of bull kelp was lost along 350 km of coastline, sea urchin density increased 60-fold, the sunflower star became locally extinct, and red abalone (*Haliotis rufescens*) declined via starvation by up to 96%, resulting in the closure of its productive fishery in California and Oregon (292 mt per year) [9,10].

Curiously, despite widespread kelp loss to the north (British Columbia) and south (Oregon), canopy-forming kelp along the Outer Coast appear to have largely recovered after a relatively minor decline associated with the 2013-2015 anomalous climate events (Helen Berry, DNR; Dr. Andrew Shelton, NMFS). Despite experiencing widespread sea star wasting, the rapid kelp rebound suggests the Outer Coast may exhibit a degree of resilience (i.e., the capacity to recover after a disturbance). The exact reason(s) why remain(s) unclear. At a regional scale (e.g. coastal Washington versus Oregon), it is possible the local sea otter (*Enhydra lutris kenyoni*) population contributed to this resilience [11,12]—yet patches of urchin barrens still developed offshore of Tatoosh and the Western Strait following the 2013-2015 disturbances. Environmental drivers are important for structuring kelp dynamics along the Outer Coast [13]—yet the same broad environmental conditions lead to widespread kelp loss elsewhere. Given the likelihood of future climate-related disturbance events, understanding the health, trends, and functioning of coastal habitats and species—all required for effective conservation and management—requires additional information [14,15].

In collaboration with the Cape Flattery School District, the Makah Tribe, NMFS, OCNMS, PSRF, the Quileute Tribal School, and WDFW, we propose a pilot study to test ROV protocols for surveying coastal habitat and benthic taxa, including understory and canopy-forming kelp, invertebrates, and fishes. ROVs are a potential intermediary between ongoing SCUBA-based and aerial canopy-imagery methods of data collection. This is because SCUBA divers obtain detailed information but from relatively small survey areas, whereas aerial imagery provides vast information of canopy-forming kelp, but none about other taxa such as understory or turf algae, invertebrates, or fishes. ROVs have the potential to bridge and complement the two. *Developing additional survey capacity is especially important in remote, rugged locations where SCUBA divers are limited in their ability to access survey locations* [16]. In order to expand benthic survey capacity along the Outer Coast, we propose to rigorously test the Seattle Aquarium's new BlueROV2 (Fig. 1) south of Cape Flattery. To ensure our ROV survey methods and results are shared with local oversight and advisory entities, we propose to regularly present to the Intergovernmental Policy Council, Sanctuary Advisory Council, and Washington Coastal Marine Advisory Committee. This pilot study represents the beginning of what we hope will be a long-term monitoring program, thus we also propose to engage communities in Neah Bay and La Push through a combination of K-12 and broader community activities. It is our desire that what we learn, our methods, and our reasoning for studying these ecosystems is shared with those living closest to them.

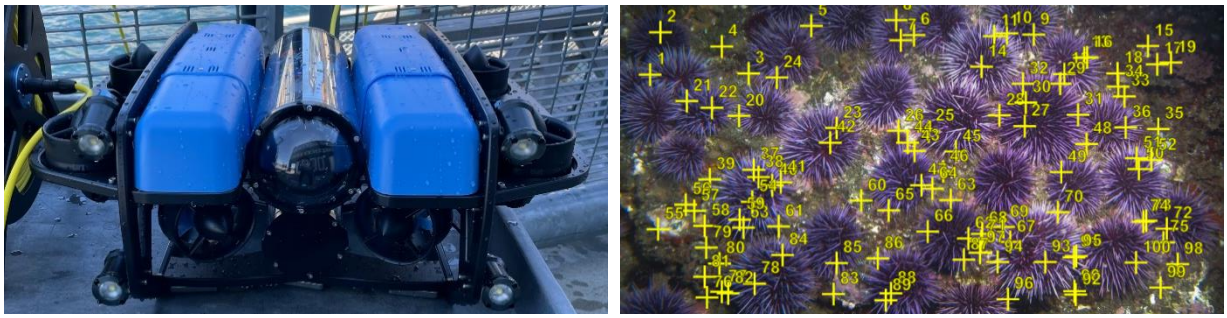

Fig. 1: **Left**: the Seattle Aquarium's ROV following an initial dive in Puget Sound down to 70'. **Right**: A screenshot of CoralNet after applying a trained machine learning algorithm to an unseen image. At each of the 100 randomly generated points (yellow "plus" signs), the algorithm determines whether urchin, bare rock, water, fish, or other is present. We envision using CoralNet to calculate percent-coverage from photo stills, and VIAME to track abundances of conspicuous species such as sea urchins, sea stars, certain kelp, and fishes from ROV obtained video.

(c) Appropriateness of project to NPC MRC objectives

This project will directly contribute to three benchmarks developed by the Coastal MRC Work Group: ***Marine Habitats****:* Our study will provide detailed information regarding abundances/percent-coverage of benthic kelp, invertebrates, and fishes, and we will gain a better understanding of the size and distribution of urchin barren, understory algae, and canopy kelp patches, particularly around Cape Flattery (**1.1**) & (**1.2**). ***Sound Science****:* Our project will expand upon (1) established ROV protocols used in deeper water and (2) existing AI algorithms to develop relatively shallow-water ROV survey protocols and AI-based imagery analyses that will enhance our capacity to understand benthic species along the Outer Coast (**1.1**—**2.2**). ***Education and Outreach****:* Our engagement activities will inform the public (**3.1**) and students in Neah Bay and La Push (**3.2**) about the current state of coastal habitats and species, as well as challenges facing these ecosystems due to the increasing frequency and intensity of climate-change related disturbances such as anomalous warm-water, marine disease, and hypoxia events. We will also proactively share our methods and results and coordinate with various oversight, regulatory, and advisory entities (**4.1**).

(d) Project objectives and (e) Timeline

Develop, test, and implement ROV protocols to survey relatively shallow (5-40m) benthos via video

(**1.1**) Gather imagery of the benthos via ROV offshore of Cape Flattery; test and repeat as necessary. Develop standardized protocols to operate a small ROV in relatively shallow (5-40m) waters.

(**1.2**) Fly the ROV along similar transects that NMFS divers survey at the OCNMS subtidal sites.

Train, apply, and make accessible CoralNet and VIAME machine learning algorithms and tutorials

(**2.1**) Extensively train CoralNet and VIAME algorithms from (**1.1**) imagery.

(**2.2**) Compare AI-derived ROV data to SCUBA survey data from (**1.2**).

(**2.3**) Develop and post trained algorithms and AI tutorial content so that others can conduct analyses.

Engage with communities in Neah Bay and La Push

(**3.1**) Work with Bill Monett to conduct a Schools Without Walls event about ROV surveys in Neah Bay.

(**3.2**) Work with Alice Ryan at the Quileute Tribal School and Camden Jones at Neah Bay High School to develop lecture content about kelp forests in a changing climate; work with Alice, Camden, and Nicole Harris (OCNMS) to develop ROV-based field trips and MATE ROV engagement activities.

Engage with oversight entities in the planning of a broader, long-term subtidal monitoring program

(**4.1**) Present to and coordinate with the Intergovernmental Policy Council, Sanctuary Advisory Council, and Washington Coastal Marine Advisory Committee.

(**4.2**) Use results from pilot study to apply for proposals to initiate long-term Outer Coast program.

(**4.3**) Deliver final report and present to the NPC MRC.

Project Objectives	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
(**1.1**) Fly and test ROV south of Cape Flattery		X	X	X						
(**1.2**) Fly the ROV above OCNMS index sites					X					
(**2.1**) Train AI algorithms on (**1.1**) imagery		X	X	X						
(**2.2**) Compare AI and diver-data from (**2.1**)					X	X				
(**2.3**) Create and post AI tutorial content						X	X	X		
(**3.1**) Schools Without Walls event in Neah Bay			X	X						
(**3.2**) Visit QTS and NBHS; ROV field trips	X	X	X					X	X	X
(**4.1**) Present to oversight councils	as requested, as appropriate									
(**4.2**) Apply for proposals to start full project							X	X	X	X
(**4.3**) Deliver final report to NPC MRC										X

(f) Methods

1. *Develop, test, and implement ROV protocols to survey relatively shallow (5-30m) benthos via video*
September 2021, we assembled a Blue2ROV at the Seattle Aquarium (Fig. 1) and tested it in Puget Sound. We are currently incorporating an image-stabilized GoPro HERO10 and two lights underneath the ROV. We will iterate with camera and light placement and settings at the Seattle Aquarium to ensure the ROV gathers high-resolution (4K) imagery as desired. The pilot study will formally begin (**1.1**) by operating a vessel out of Neah Bay (chartering either an OCNMS, MFM, or a Makah vessel) just south of Cape Flattery. There we will fly the ROV along areas of the benthos characterized by urchin barrens (e.g., around Tatoosh Island), understory algae, and canopy-forming kelp. These trials will provide ample opportunity to modify and refine ROV handling and imaging protocols. July 2022, we will (**1.2**) accompany OCNMS and NMFS personnel and fly the ROV around the five OCNMS monitoring sites [11]. We will charter a third vessel as a dedicated ROV platform to accompany the OCNMS and NMFS vessels. We will survey above *and* around the SCUBA transects to gain a broader understanding of community structure at these index sites. These surveys will also allow comparison between ROV- and SCUBA-collected benthic data.

2. *Train, apply, and make publicly available CoralNet and VIAME machine learning algorithms.*
In tandem with (**1.1**), we will (**2.1**) expand upon our initial CoralNet percent-cover analyses of images (Fig. 1) to train object detection and tracking from video in VIAME. We will track the abundance and position of conspicuous species such as demersal fish, sea stars, sea urchins, some anemones, and certain kelp from benthic imagery, as well as midwater fishes from the forward-facing camera [17,18]. Size estimation will be explored once additional camera and light equipment is incorporated. Complexity can be layered in VIAME. For example, an algorithm previously trained on sea stars can later be trained to detect urchins. The more imagery we annotate—and the more we review and correct algorithm predictions—the more capable our algorithms become. As new species/categories are trained, we can reanalyze previously processed imagery to produce new insights. To (**2.2**) understand how imagery processed by AI contrasts with diver collected data, we will extend the approach from [19] to AI-derived data. Finally, (**2.3**) Randell will develop AI tutorial content via screen-sharing and recording in Zoom to demonstrate the process of training an algorithm. These tutorials will be posted on YouTube so that others can apply the methods. All algorithms originate from open-source projects, and all trained algorithms will be public on GitHub.

3. *Engage with communities in Neah Bay and La Push*
There are many ways in which the motivation, methods, and results of this project can be shared with coastal communities, both in the K-12 setting and among the broader community. As the waters we propose to work in for (**1.1**) i.e., around Cape Flattery, are all part of the Makah Tribe's Usual and Accustomed Fishing Area (U&A), we have partnered with them on all aspects of this project. Broadly, for this pilot study we propose to first focus our community engagement within Neah Bay and La Push, and then in the future—see **(h)** below—as the broader long-term program we envision unfolds, we will expand the scope and locations of these activities. Specifically for this pilot study, we propose to (**3.1**) work with Bill Monette to host a Schools Without Walls event in Neah Bay, where we will fly the ROV in the marina (e.g., around marine shipwrecks) to demonstrate our benthic survey methods to the Neah Bay community. We also propose to (**3.2**) work with Alice Ryan at the Quileute Tribal School and Camden Jones at Neah Bay High School to develop lectures about why we are studying kelp forests, how we go about it, and what we hope to learn. We will work with Alice and Camden to develop field trips centering around the ROV, allowing students to see through the camera of the ROV in real time. This will reveal life along the seafloor right off

of Neah Bay and La Push that students might not otherwise normally experience. Finally, we will work will Bill, Alice, and Camden to explore other ways we can use the ROV in existing curricula or activities. For example, in partnership with Nicole Harris at OCNMS, we will work with the MATE Olympic Coast Regional ROV Competition in 2022: we will bring our ROV to pool sessions to demonstrate how we use it for surveys, and Randell could serve as a judge at the competition in May.

4. *Engage with oversight entities about pilot study results and the planning of long-term program*
No one individual or organization can tackle the challenges facing coastal systems alone. In this spirit we are excited to partner with the Cape Flattery School District, the Makah Tribe, NMFS, OCNMS, PSRF, the Quileute Tribal School, and WDFW for this pilot study. The extensive experience of our partners will help connect our project with regulatory and oversight entities and the broader coastal research community. There are numerous individual and overlapping management and conservation interests that our data will inform. For example, rockfish, sea urchin, and sea cucumber abundances can all assist Washington stock assessments [3,20], and information regarding Pinto Abalone along the Outer Coast will help inform PSRF's recovery efforts [21]. To (**4.1**) ensure all stakeholders and decision makers are apprised of our project, we will regularly present to the Intergovernmental Policy Council, Sanctuary Advisory Council, and Washington Coastal Marine Advisory Committee. In the course of this pilot study Randell will (**4.2**) apply to additional proposals to help initiate the broader long-term program we envision (discussed below). Randell will also (**4.3**) prepare and present a final report to the NPC MRC at the conclusion of this pilot study, and he will provide regular status updates and/or presentations to the NPC MRC upon request.

(g) Extent or impact of the project

We are unable to state how many meters squared (m^2) we will survey with the ROV. Area surveyed (m^2) per unit effort (e.g., 1 hour driving the ROV) given a consistent ROV speed (e.g., 0.5m per second) is one of many rate processes and survey protocols that have yet to be established—but are of focal interest to the pilot study. However, to air some speculation here: our partners at NMFS recently tested a similarly-sized ROV in the Duwamish Waterway around Harbor Island. In 40min they filmed an area approximately 120 x 30m. To place that in context, in 40min a scientific SCUBA diver can complete between one and three (depending on survey type, species present, bottom conditions, etc.) 30 x 2m invert/algae or 50 x 4m fish transects. Assume they complete three. That is $3600m^2$ for the ROV vs $180m^2$ or $600m^2$ for the divers. ROVs have significant potential that has yet to be fully tapped in shallow (5-40m) benthic ecosystems.

(h) Plans to continue the project into the future

If funded, this pilot study would be the first step towards a long-term Outer Coast monitoring program. *This entire proposal represents the Seattle Aquarium's desire to invest in research and community engagement along the Outer Coast.* To lay the groundwork for a long-term program, we are communicating with resource management representatives from the Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation. Randell looks forward to future conversations to learn ways in which our ROV and AI methods can be applied to questions of local interest. For example, after talking with a Quileute Tribe resource manager, in the future we could conduct ROV surveys along soft-sediment areas and use AI to calculate abundances of clam siphons, halibut, and polychaete worms (when their feeding structures are visible). And as the ROV is rated to 100m, there is much potential for surveying deeper reef and soft-sediment locations. Randell anticipates spending significant time on the Outer Coast. He is excited to have the opportunity to engage all coastal communities, and to share our motivation and methods for—and our results from—studying the health, trends, and functioning of benthic ecosystems along the Outer Coast.

10. Project Budget

Category	Detail	MRC Request	Matching Contribution	Total
Salaries and Benefits or hourly wages	Partial funding to create a position for Randell at the Seattle Aquarium	**$20,000**	$20,000 from the Seattle Aquarium, for existing staff to assist with this project	$40,000
Supplies/Equipment	Topside hub and acoustic receiving station for GPS tracking system.	**$4,800**	$5,150 from the Seattle Aquarium to purchase the other components of the ROV tracking system and a camera	$9,950
Travel	NA	NA	$15,000 from the Seattle Aquarium for all travel associated costs of fieldwork along the Outer Coast (food, lodging, etc.).	$15,000
Contracted services	NA	NA	$10,000 from the Seattle Aquarium for costs associated with 15 days of vessel charters (vessel gas, daily fee, etc.)	$10,000
Indirect expenses	NA	NA	NA	NA
Other	NA	NA	NA	NA
Totals		**$24,800**	**$50,150**	**$74,950**

1. Personnel salaries and benefits: We are requesting $20,000 to help create a position for Zachary Randell at the Seattle Aquarium (100% FTE=$65,000/year). Randell will work full-time starting in February to complete all tasks articulated in this proposal. Past 2022, he will also be responsible for leading the longer-term Outer Coast research and monitoring program that we envision this pilot study will help spark. This funding is necessary as we are seeking to create a new position. If we were not in "Covid-19 times," it is likely the Seattle Aquarium could create this position itself. However, given the pandemic—and the loss in revenue associated with two closures of the Seattle Aquarium—the entirety of funding necessary to create a position for Randell in 2022 is not available. Once clear of 2022 (i.e., in 2023), the Seattle Aquarium intends to bring Randell's funding under General Operations, and thus he would be able to lead this program long-term. The $20,000 would go to Randell's salary, and he would work on this pilot study's field work, analyses, and engagement full-time for all of 2022 starting in February. The Seattle Aquarium is arranging—via shuffling budget items, other grants, and donations—the rest of Randell's salary for 2022.

Matching funds: The Seattle Aquarium will contribute $20,000 in salary—in personnel time—to work on this project with Randell. Specifically, Shawn Larson, Curator of Conservation Research at the Seattle Aquarium, will work extensively with Randell during the course of this pilot study to help coordinate among partners and engage in outreach. Personnel time from two of Shawn's technicians—Amy Olsen and Alex Tanz—is also being diverted to assist this project. Specifically, they both (and Shawn) will accompany Randell in the field to drive the ROV, and all four (including Randell) will conduct scientific SCUBA operations in the testing phase of this pilot study.

2. Supplies/Equipment:
We have budgeted to purchase an underwater GPS tracking system for the ROV. The Underwater GPS G2 system (linked here) would provide and record a live feed of the ROV's position relative to the boat. Such tracking ability is essential in order to (1) survey a standardized area, i.e., survey transects of a consistent length; (2) ensure we survey the same area when returning to the same location; and (3) GPS coordinates will allow our imagery to be combined with existing acoustic side-scan sonar-derived habitat information.

In other words, with GPS tracking, we can relate our abundance and percent-coverage estimates from the ROV imagery to the precise physical habitat characteristics those taxa were found upon. This opens up numerous analytical options (e.g., habitat-suitability modeling) such that GPS tracking will significantly amplify the impact of our ROV surveys.

There are five distinct components necessary for the Underwater GPS G2 tracking system. We are requesting MRC funds for two of those parts:

1. Acoustic Positioning system: $2,800. This is the topside component that receives a GPS fix and communicates with the user's laptop.
2. Submerged Acoustic Antenna: $2,000. The antenna is affixed to the vessel and submerged in the water. It receives acoustic information from the Locator UI unit affixed to the ROV.

Matching funds: The Seattle Aquarium will purchase:

3. Locator U1: $1,500. The Locator (an acoustic transmitter) is affixed to the ROV. The acoustic signal emitted by this transmitter is received by the Submerged Acoustic Antenna.
4. R300 software: $2,800. The R300 software provides 300m range to ensure consistent acoustic communication. This added range will be important when surveying in thick kelp.
5. BlueROV2 Integration Kit: $400. The integration kit provides the cables and microcontroller boards necessary to integrate the GPS G2 unit with our ROV.

The Seattle Aquarium will also purchase a GoPro HERO10 ($400) and underwater case ($50).

3. Travel: The Seattle Aquarium had budgeted $15,000 to pay for all food, lodging, and transportation costs required to conduct field work and engagement activities along the Outer Coast. These costs are associated with completing field work objectives (**1.1**) and (**1.2**), as well as engagement activities (**3.1**) and (**3.2**) Typical costs for lodging are $300 per person, per day. We will send two staff members for each scheduled day of fieldwork. In 2022 we budgeted enough for two people to spend 25 days (15 fieldwork days, 10 engagement days) on the Outer Coast. (Day trips that do not require lodging are not represented here).

4. Contracted Services: the Seattle Aquarium will provide $10,000 to pay for all costs associated with chartering vessels to run the ROV south of Cape Flattery. The Seattle Aquarium's vessel operates within Puget Sound and the Strait of Juan de Fuca. It is older and not suited for Outer Coast operations. Until the Seattle Aquarium obtains a new vessel, we will charter day-trips to fly the ROV around Cape Flattery for objective (**1.1**), and offshore of Koitlah Point, Tatoosh Island, Cape Alava, Cape Johnson, and Destruction Island for objective (**1.2**). At a minimum, we propose 10 days of vessel charters to complete (**1.1**)—these can be standalone days or back-to-back if we have a good weather window. To complete (**1.2**) will require 5 consecutive days chartering a vessel.

Personnel from Makah Fisheries Management (MFM) have offered the use of their vessel. This would involve a $100-$200 daily fee (primarily to cover gas). We are also exploring the possibility of chartering a local Makah vessel out of Neah Bay, which—according to MFM personnel—would likely involve covering gas and a daily fee. We can also charter a 22' OCNMS Rigid Hull Inflatable Boat (RHIB) with cockswain (including housing for a night) at $750/day.

Given these options, the Seattle Aquarium will charter a MFM vessel for 10 days to complete (**1.1**): 10 days x $200 per day = $2,000. We will also charter the OCNMS RHIB for 5 days to complete (**1.2**): 5 days x $750 per day = $3,750. Total estimated charter costs = $5,750. With $10,000 budgeted, we have contingency costs built in (e.g., if MFM personnel request their time to be compensated when chartering one of their vessels) to ensure both (**1.1**) and (**1.2**) are successfully completed.

5. Indirect Expenses: NA
6. Other: NA

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Letters of Support (alphabetically listed by last name)

Washington Department of Fish and Wildlife

- **Dr. Henry Carson**, *Research Scientist*

United States Department of Commerce, National Ocean and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center

- **Dr. Blake Feist**, *Landscape Ecologist*

Makah Fisheries Management

- **William Jasper**, *Groundfish Biologist*

United States Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Olympic Coast National Marine Sanctuary

- **Anne-Marie Runfola**, *Acting Superintendent*

Quileute Tribal School District

- **Alice Ryan**, *Teacher*

Puget Sound Restoration Fund

- **Dr. Jodie Toft**, *Deputy Director*

Curriculum Vitae (CVs) attached

Dr. Zachary Randell, *Special Projects Volunteer,* Seattle Aquarium

Dr. Shawn Larson, *Curator of Conservation Research*, Seattle Aquarium

State of Washington
Department of Fish and Wildlife

Mailing Address: 600 Capitol Way N, Olympia WA 98501-1091, (360) 902-2200, TDD (360) 902-2207
Main Office Location: Natural Resources Building, 1111 Washington Street SE, Olympia WA

October 29, 2021

Dear Review Committee,

The Washington Department of Fish and Wildlife (WDFW) has a strong history of collaboration with the Seattle Aquarium, and submits this letter of support for the Seattle Aquarium's North Pacific Coast Marine Resources Committee proposal titled "Remotely Operated Vehicle (ROV) testing and Artificial Intelligence (AI) analyses: a pilot study to spark a long-term subtidal Outer Coast monitoring program".

WDFW recognizes that the proposed project represents an important step in unlocking much needed information for a suite of fish and invertebrate species we manage, including those subject to fisheries or of high management concern. Additionally, the proposed research will have management implications for sea otters, which are identified as a Species of Greatest Need under the Washington State Wildlife Action Plan. Establishing methods to fill the data gaps that exist for many of these species, in the long term, will improve our understanding of their use of coastal habitats. This is turn will lead to improved stock assessments and more informed management of coastal ecosystems. For instance, much-needed data on the distribution of pinto abalone on the outer coast will inform the recovery strategy for this endangered species. The proposed research would also dovetail nicely with current WDFW investigations of kelp forest and sea urchin interactions in the Western Strait of Juan de Fuca.

WDFW staff will participate as collaborators on the project, as technical advisors on various aspects of the proposed sampling designs, equipment, and techniques, and also as potential participants in the research activities and analysis. In discussions of the project proposal, staff with extensive ROV expertise provided input on the ROV component of the project and intend to maintain this working relationship with the project investigators. The WDFW shellfish dive team shared knowledge regarding scuba survey methods and species of concern. Because comparatively little undersea research has been done on Washington's outer coast, this proposal lays the groundwork to fill key knowledge gaps with ROV and dive techniques.

WDFW is in full support of the Seattle Aquarium's North Pacific Coast Marine Resources Committee proposal as we believe the data collected will produce significant advancements in the understanding of our state's coastal ecosystems.

Sincerely,

Dr. Henry Carson
Research Scientist
Washington Department of Fish and Wildlife
1111 Washington St. SE, Olympia, WA 98501
(360) 902-2846 henry.carson@dfw.wa.gov

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Fisheries Science Center
2725 Montlake Boulevard East
SEATTLE, WASHINGTON 98112-2097

F/NWC1

5 November 2021

To whom it may concern:

I am very pleased to provide this letter of support on behalf of Dr. Shawn Larson and Dr. Zachary Randell and colleagues and their proposal, "Remotely Operated Vehicle (ROV) testing and Artificial Intelligence (AI) analyses: a pilot study to spark a long-term Outer Coast monitoring program." Moreover, I have agreed to be a close collaborator on this project should the proposal be funded.

I am a member of the Ecosystem Science Program at NOAA's Northwest Fisheries Science Center in Seattle, WA, which consists of a team of scientists with multi-disciplinary interests related to marine ecosystem-based management. One of our ongoing research priorities is the study of natural and human-driven processes affecting kelp forest communities in the Olympic Coast National Marine Sanctuary (OCNMS), and how those dynamics relate to fishing communities that rely on kelp forest resources. I believe that the proposed project will address important questions regarding the feasibility of ROVs to sample within and adjacent to kelp forest ecosystems. The information gained will be valuable to coastal zone management, fisheries, and conservation efforts.

Our Program has been performing subtidal SCUBA surveys of kelp forest habitats within the OCNMS since 2015. These surveys have led to a better understanding of kelp forest community dynamics, but have been limited in scope due to personnel capacity. Funding the current proposal will provide resources to add several lines of investigation related to the connectivity of protected and unprotected areas, including 1) connectivity between the shallow communities we have been surveying and the deeper rocky reef habitats that the proposed ROV research will allow, 2) increase capacity along the rugged, rural Washington coast for long-term monitoring of these productive habitats with an eye on understanding long-term effects of climate variability on kelp forest and fisheries community dynamics, and 3) dovetail with our existing pilot project to test the capability of using ROVs to sample inter- and sub-tidal marine habitats.

This work is critical to Sanctuary, Washington State, and NOAA Fisheries missions along the Washington coast, and we enthusiastically support it for funding.

Sincerely,

Dr. Blake Feist
Landscape Ecologist
Northwest Fisheries Science Center
blake.feist@noaa.gov

MAKAH TRIBE

P.O. BOX 115 • NEAH BAY, WA 98357 • 360-645-2201

Dear Ms. Pokorny and NPC MRC Review Committee Members,

I am writing to express my support for the Seattle Aquarium's (SA) proposal to the North Pacific Coast Marine Resources Committee titled: "Remotely Operated Vehicle (ROV) testing and Artificial Intelligence (AI) analyses: a pilot study to spark a long-term Outer Coast monitoring program". The Seattle Aquarium proposes to complete a pilot study using a ROV to survey relatively shallow seafloor and kelp forest ecosystems, and machine learning techniques (AI) to document individually countable macroalgae and invertebrates, percent cover of colonial/expansive macroalgae and invertebrates, and benthic and midwater fishes. The Seattle Aquarium proposes to fly an ROV south of Cape Flattery along areas where they can test ROV handling above urchin barrens, understory algae, and within canopy forming kelp. These tests will provide key information, including whether ROVs can serve as part of a long-term subtidal monitoring program.

Critically important species (such as rockfish and salmonids) recruit, feed, and spawn in and around kelp forests. Moreover, kelp forests are an integral part of the marine ecosystem in the northwest; making them a critical component of any ecosystem-based management efforts. Monitoring these environments is paramount for documenting the effects of episodic changes in the abundance of sea stars and urchins, ocean acidification, pervasive marine heat waves, and climate change on local kelp forest ecosystems. However, the historic method of conducting these monitoring efforts (dive transect surveys) faces unavoidable limitations; related to necessary safety measures and logistics. There is increasing interest in supplementing high-resolution, spatially focused data obtained by scientific dive teams with the more broad-scale survey data collected by more easily and safely deployed ROVs. This pilot study's concept of combining novel survey techniques with machine learning software has the potential to radically increase the capacity of the relatively resource challenged communities and management entities of Washington's Outer Coast.

I have committed to being a full partner on this markedly well-timed proposal, and will collaborate with Zach Randell and staff at the Seattle Aquarium in all aspects of this project. It is my professional opinion that this study is of deep value and importance to groundfish and shellfish management, and I can attest that the lessons and techniques produced by this project would be of immediate and profound benefit to my own endeavors. I look forward to working with Dr. Zachary Randell, Dr. Shawn Larson, and their team at the Seattle Aquarium and fully recommend the funding of this proposal.

Kind Regards,

Will Jasper

William Jasper
Groundfish Biologist
Makah Fisheries Management
PO Box 115
Neah Bay, WA 98357
Phone (Office): 360-645-3157
Phone (Cell): 360-640-1662

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE

Olympic Coast National Marine Sanctuary
115 E. Railroad Ave , Suite 301
Port Angeles, Washington 98362

8 November 2021

Tami Pokorny
North Pacific Coast MRC
Clallam and Jefferson Counties, WA

Dear Ms. Pokorny and NPC MRC review committee members,

On behalf of Olympic Coast National Marine Sanctuary, I am writing to express strong support for a proposal submitted by Dr Zachary Randell of the Seattle Aquarium and collaborators focused on using remotely operated vehicles (ROV) and artificial intelligence to develop and test methods and protocols for monitoring kelp forests and adjacent habitats at sites on the Olympic Coast and in the westernmost portion of the Strait of Juan de Fuca.

If selected for funding, the proposed work aims to apply new technology and techniques in an effort that we believe will leverage and create linkages among several ongoing sanctuary efforts, including our annual summertime scuba surveys of kelp forests with NOAA's Northwest Fisheries Science Center and the MATE ROV student competition for the Olympic Peninsula, which is led by our own Nicole Harris. In addition to building on existing efforts, the project also has the potential to greatly enhance monitoring capacity within important habitats in the sanctuary, increasing cost effectiveness of field activities while expanding the temporal and spatial coverage of monitoring efforts along this remote and often challenging coastline. By focusing this work on nearshore habitats like kelp forests, rocky reefs and sandy seafloor areas, we expect this project will reveal new information to describe these often understudied habitats and the communities they support, and illuminate new opportunities and partnerships that will further advance our collective understanding of ecosystem function and connectivity in future. Engaging local youth in the work promises to benefit both the project and the students, helping to build career pathways by offering students opportunities to engage with regional scientists in a meaningful, collaborative way.

If the project is funded, OCNMS Research Ecologist, Jenny Waddell, will serve as a collaborator in this effort, coordinating this work with other sanctuary field activities and programs and helping to implement the project; Resource Specialist, Katie Wrubel will likewise be engaged in coordination, permit consultation and project implementation efforts.

Sincerely,

RUNFOLA.ANNE.MARIE.1456501970

Digitally signed by RUNFOLA.ANNE.MARIE.1456501970
Date: 2021.11.08 17:16:48 -05'00'

Anne-Marie Runfola, Acting Superintendent
Olympic Coast National Marine Sanctuary

Quileute Tribal School District
P.O. Box 39
La Push, WA 98350
360-374-5648, FAX 360-374-9608

The mission of the Quileute Tribal School is for all students to gain and retain the knowledge and skills necessary to make them responsible, productive citizens. They will develop problem solving skills, communication skills, and self- sufficiency skills that will allow them to interact at all levels of society. They will protect, preserve and enhance the Quileute language and culture for future generations.

11/5/21

Dear Review Committee,

I am writing to express my excitement for the Seattle Aquarium's proposal to the North Pacific Coast Marine Resources Committee titled: "Remotely Operated Vehicle (ROV) testing and Artificial Intelligence (AI) analyses: a pilot study to spark a long-term Outer Coast monitoring program".

The Seattle Aquarium intends to conduct surveys of the seafloor with a ROV, analyze data with Artificial Intelligence methods, and engage classrooms such as mine. The Seattle Aquarium plans to work with my students at Quileute Tribal School in La Push WA. as they undertake the MATE ROV competition. Specifically, they plan to bring their ROV into my classroom and to present on the some of the challenges facing coastal systems, including changing climate conditions. We also plan to develop a field trip centered around the ROV, such that all the students in a class could walk outside and experience the seafloor by viewing a laptop which receives a live video feed from the ROV. This will provide a unique opportunity for our students to observe life along the seafloor.

We intend to stay in touch as the Seattle Aquarium's project gets underway. Most immediately, the project lead, Zachary Randell, will join one of our ROV team meetings. The students could meet Zach and talk about their ROVs and the specific components they are working on. Zach will prepare a short presentation showing the Seattle Aquarium's ROV, as well as footage from upcoming ROV tests. The next step would be for Zach to bring in the ROV and meet the students in person (Covid-19 allowing). It is our hope that providing students the opportunity to experience this research-focused ROV will spark ideas for how to build or modify their own ROVs for the MATE competition in May. This experience will also allow students to explore in more depth possible futures utilizing ROVs, collecting data, doing research and connections with the Seattle Aquarium.

There are likely many other ways in which we can work together and expose students to coastal research. I look forward to working with Zachary Randell and Shawn Larson.

If you have any further questions, please do not hesitate to contact me.
Alice Ryan

(406)546-9893 alice.ryan@quileutetribalschool.org

PUGET SOUND
RESTORATION FUND

8001 Day Road West, Ste. B
Bainbridge Island, WA 98110
www.restorationfund.org
(206) 780-6947

October 28, 2021

Dear Review Committee,

This letter represents Puget Sound Restoration Fund's (PSRF) support for the proposal, "Remotely Operated Vehicle (ROV) testing and Artificial Intelligence (AI) analyses: a pilot study to spark a long-term Outer Coast monitoring program," submitted by Principal Investigator Zachary Randell for funding from the North Pacific Coast Marine Resources Committee. Results from the proposed work will substantially advance our ability to effectively and efficiently monitor our marine environment, including two important members – bull kelp and pinto abalone.

PSRF has been restoring foundational elements of Puget Sound's marine ecosystem since 1999, with a focus on native species, including Olympia oysters, pinto abalone, and bull kelp. Our bull kelp habitat restoration program has gained momentum in recent years due to an expressed need from partners and stakeholders to identify robust solutions to kelp loss in our region and beyond. One of the challenges we face is to track changes in the abundance, distribution and health of bull kelp throughout the region. This challenge is reflected in the 2020 Puget Sound Kelp Conservation and Recovery Plan, which we co-authored with many of these partners – a document that outlines research and restoration needs for kelp in the Puget Sound region. The challenge is simply due to the high cost of performing underwater surveys with teams of divers. With advances in technology and computing systems, the proposed work is an essential step towards facilitating accurate tracking of our underwater forests. While the majority of the bull kelp work we do is in Puget Sound, methods developed in the proposed work off of Neah Bay and surrounding areas can be applied to our study region as a next step. Further, the proposed methods can be applied to efforts to recover pinto abalone – listed as endangered in Washington State – for which we are a co-lead (with Washington Department of Fish and Wildlife) for population rebuilding, and which the Seattle Aquarium has recently become one of our primary partners.

We are pleased to serve as collaborators on the proposal. In doing so, we will work as part of the team to ensure that the benthic imagery collected can be accurately used to assess trends and habitat conditions for two of PSRF's focal species – bull kelp and pinto abalone. In addition, we will work with this qualified, cross-cutting team to translate findings into conservation and restoration actions through biannual meetings.
We look forward to supporting this important, timely project.

Sincerely,

Jodie Toft, Deputy Director

Zachary Randell

(408) 660-7842 | z.randell@seattleaquarium.org | randellz@oregonstate.edu | zhrandell@gmail.com

Education

Oregon State University — Corvallis, OR
Doctor of Philosophy in Integrative Biology | Minor in Statistics — *2015—2021*
Ph.D. dissertation | Public defense on YouTube
Sea Otter Foundation and Trust grant recipient to purchase a ROV *2020*
Dr. Earl H. Myers & Ethel M. Myers Oceanographic & Marine Biology Trust Recipient *2019*
NSF Graduate Research Fellow *2016—2019*

University of California Santa Cruz — Santa Cruz, CA
Bachelors of Science in Biology — *2008—2012*
Senior thesis awarded Honors
UC Santa Cruz Diving Control Board Undergraduate Representative *2010—2012*

Analytical and Field Skills

Languages : *R*, Mathematica, LaTeX, Stan

Analysis : proficient – multivariate analyses, dynamical modeling, Bayesian statistics; learning – spatial analyses

Tools : open-access research and version control on GitHub

Scientific SCUBA diving : 652 scientific SCUBA dives: benthic invertebrate, algae, fish surveys; sample collections; oceanographic equipment installation, maintenance and retrieval; index site installation; underwater pneumatic drilling; underwater photography / videography; Dry Suit, Rescue, Nitrox certified; AAUS certified to $100'$

Scientific rebreather diving : 100% O_2 Closed-Circuit Rebreather certified for sea otter capture operations

Small boat operations : 289 separate days as Primary Operator on inflatables, Boston Whalers, Andersons, and Radon vessels ($8 - 25'$); Motorboat Operator Training Certification obtained at UC Santa Cruz *2011*; extensive experience operating vessels in nearshore waters such as kelp forests including diver deployment and retrieval operations

Subtidal experimentation : Designed and executed a subtidal caging experiment; responsible for organizing and leading undergraduate volunteers, interns, and employees in the field

Radio telemetry tracking : Conducted RF based tracking and surveillance of tagged sea otter individuals; collected visual observations including foraging activity

Work Experience

Biological Science Technician & Volunteer — Santa Cruz, CA
U.S. Geological Survey, Western Ecological Research Center — *2012—2015, 2015—*

- Partner on NASA-USGS collaboration developing novel sea otter tag technology. My role was to facilitate communication between electrical and structural engineers at Moffett Field, USGS biologists, and Monterey Bay Aquarium personnel. I guided the design of a $3D$ printed "shell" protecting the tag, and developed methods to encapsulate the electrical components and $3D$ printed shell within optical resin. Learn more here. here, and here.
- Radio telemetry tracking of sea otters implanted with VHF transmitters along the central and southern CA coast
- Sea otter captures: experienced in the capture, handling, transport, and release of wild sea otters
- Subtidal SCUBA operations throughout central California and the Channel Islands

Graduate Teaching Assistant & Instructor — Corvallis, OR
Oregon State University — *2015, 2019—2021*

- Principals of Biology BI221, BI222, BI223: Cells, Organisms, Populations (ten quarters)
- Human Anatomy and Physiology BI241 (two quarters)

Subtidal Technician — Santa Cruz, CA
Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO) — *2010 & 2011 field seasons*

- Benthic surveys of subtidal and mobile invertebrates, macroalgae, and benthic, midwater, and canopy fishes
- Deployed, maintained, and retrieved oceanographic monitoring equipment
- SMURF (Standard Monitoring Unit for the Recruitment of Fishes) skin diving collection, fish identification, and fin clip sampling

Publications

Randell, Z.R., Kenner, M., Tomoleoni, J., Yee, J., Novak, M. (***in review***) Kelp-forest dynamics controlled by substrate complexity, In: *PNAS*.

Randell, Z.R., Sheridan, C., Bray, J., Carr, M., Novak, M. (***in prep***) Urchin consumption of kelp controlled by the density of drift, In: *Ecology Letters*.

Novak, M., **Randell, Z.R.**, *et al.*, (***in review***) Ecosystem stability and the fraction of feeding predators. In: *Nature Ecology and Evolution*.

Glidden, C., **Randell, Z.R.**, *et al.* (***in review***). Strategies for managing marine diseases. In: *Ecological Applications* https://doi.org/10.32942/osf.io/umvae

Grorud-Culvert, K., **Randell, Z.R.**, *et al.* (2019). High-profile international commitments for ocean protection: empty promises or meaningful progress? In: *Marine Policy* https://doi.org/10.1016/j.marpol.2019.04.003

Gravem, S.A., **Randell, Z.R.** *et al.*, (2017). Transformative research is not easily predicted. *Trends in Ecology & Evolution*. https://doi.org/10.1016/j.tree.2017.08.012

Tinker, M.T., **Randell, Z.R.**, *et al.*, (2017). Southern sea otter range expansion and habitat use in the Santa Barbara Channel, California. U.S. Geological Survey open-file report 2017-1001. https://doi.org/10.3133/ofr20171001

Select Professional Talks

Randell, Z.H., *et al.*, "An emerging long-term monitoring program to evaluate kelp-forest complexity, connectivity, and resilience along the Western Strait and Outer Coast" *Puget Sound Kelp Monitoring and Research Work Group* 2021

Randell, Z.H., "Urchin consumption of kelp controlled by the density of drift" *StanConnect Ecology* 2021

Randell, Z.H., *et al.*, "Proposed research: kelp-forest complexity, connectivity, and resilience with and without keystone predators along the Olympic Coast" *Sea Otter Conservation Workshop* 2021

Randell, Z.H., *et al.*, "Sea urchin behavior controlled by the density of drift algae: a one-consumer, two-resource functional response experiment" *Western Society of Naturalists* 2020

Randell, Z.H., *et al.*, "Velocity of community shift and alternative states in southern California kelp forests", invited speaker at *Spring Seminar Series in Department of Mathematics*, Oregon State University, 2019

Randell, Z.H., *et al.*, "Advancing tag technology: a tracking network for oiled and rehabilitated sea otters", invited speaker at *Oilapalooza: Oiled Wildlife Care Network Research Symposium*, 2019

Randell, Z.H., *et al.*, "Velocity of community shift and alternative states: how long-term monitoring can focus dialogue for nearshore conservation and management" *Sea Otter Conservation Workshop* 2017

Randell, Z.H., *et al.*, "Influence of habitat variation on 35 years of subtidal community structure at San Nicolas Island" *California Island Symposium* 2016

Randell, Z.H., *et al.*, "Game changer: solar powered peer-to-peer tracking network for oiled and rehabilitated sea otters" Invited speaker at *Oiled Wildlife Care Network Research Symposium* 2015

Service

Community Outreach and Education

Interview and blog post with Diane Tomacek, CEO and President of Sea Otter Foundation and Trust *2021*

Seattle Aquarium Light Talk—Sea Otters: "Can Sea Otters Modify the Resilience of Ecosystems?" *2021*

Mentored undergraduate interns at UC Santa Cruz and oversaw their completion of senior thesis projects *2019—2021*

Guest Lecturer at Marine Ecology and Marine Biology undergraduate classes at Oregon State *2017—2020*

Guest Lecturer at Marine Conservation undergraduate class at Pacific University *2017*

Trained Santa Barbara Zoo volunteers to conduct sea otter radio telemetry surveillance *2014*

Guest Lecturer at Salinas Valley K-12 schools on local factors imperiling sea otter recovery *2014*

Helped organize Sea Otter and Ocean Awareness Week outreach events at the Santa Barbara Zoo *2013*

Within the Department of Integrative Biology during the course of my Ph.D.

Reviewer for *Nature Communications*, *2021*

Graduate Mentor to guide 1st year Ph.D. students starting graduate school during the pandemic *2020—2021*

Graduate Representative on *ad hoc* Graduate Curriculum Review Committee *2019*

Graduate Representative on *ad hoc* Cordley Remodel Committee *2018*

Biology Graduate Student Symposium Committee *2015*, *2017*, *2018*

Organized and lectured at Integrative Biology's Community Open House event *2017—2019*

Organized special seminar speaker Ken Collins (Microsoft) to speak about private sector opportunities *2017*

Shawn Larson

Curator of Conservation Research-Seattle Aquarium
s.larson@seattleaquarium.org
206-618-3762 (c)

EDUCATION:

- University of Washington, School of Aquatic and Fishery Science, Ph.D., March 2003.
- California Polytechnic State University, San Luis Obispo. M.S., Biology, December 1992.
- University of California, Berkeley. B.S., Biology, May 1988.

CERTIFICATION:

- State of Washington Veterinary Technician: 1994 to present.
- SCUBA certification: Open water diver, 1988; Advanced open water diver, 1993; Enriched air (Nitrox), 1998; Rescue diver, 2004; Divemaster, 2009; Unified Team Diving (UTD), 2010 and AAUS Scientific Diver, 2012.
- State of Washington Wildlife Rehabilitation license: 2017

RELEVANT PROFESSIONAL EXPERIENCE:

- **Curator of Conservation Research, Seattle Aquarium**. December 1994 to present.

Specific research activities include developing facility wide relevant research projects, securing funds for research through fundraising and grant writing, facilitating and conducting projects, analyzing data, preparing results for publication in scientific journals, and disseminating results at lay and scientific meetings. In addition this position is responsible for approving and coordinating outside research projects by scientists not affiliated with the aquarium and facilitating the work of visiting researchers while at the aquarium. Current ongoing ex-situ research projects focus on reproductive endocrinology and population genetics studies of sea otters, harbor seals, sixgill sharks, and various species of seabirds or alcids. Current ongoing in-situ research projects focus on biodiversity surveys using SCUBA based video transects of rockfish in Washington State waters and of Hawaiian reef fish off the west coast of Hawaii, and sea otter population status and behavioral ecology through annual surveys and activity budget analyses. Other research projects include long term monitoring measuring of microplastics in Puget Sound and Hawaiian waters as well as within sea otters to track trophic transfer of pollutants and contaminants. All projects are multidisciplinary and collaborative involving other NGOs and local, state, federal and tribal governments. Specific water quality related activities involve oversight and management of the aquariums water quality lab including supervision of water quality staff and volunteers, overseeing water quality procedures to comply with Washington State department of ecology certification standards, and acting as a liaison between water quality staff and aquarium biologists to ensure prompt and effective communication and documentation of water quality results. Specific veterinary technical duties include assisting staff veterinarian(s) as needed in all aspects of animal care procedures and maintaining federal and state wildlife rehabilitation permits and coordinating wildlife rehabilitation including sea otters and sea turtles in Washington State under the direct supervision of staff veterinarian(s).

PEER REVIEWED SCIENTIFIC PUBLICATIONS:

1. Long, J.; **S. Larson**; and S. Wasser. 1996. Safeguarding Diversity: Challenges in Developing a Genome Resource Bank for the California Sea Otter. **Endangered Species Update**. Vol. 13. No.12. 57-60.
2. **Larson, S**. 1997. Taxonomic reevaluation of the jaguar (*Panthera onca*). **Zoo Biology**, Vol. 16, No. 2, 107-120.
3. Wasser, S.K., K.E. Hunt, J.L. Brown, K.Cooper, C.M. Crockett, U. Bechert, Joshua J. Millspaugh, **S. Larson** and S.L. Monfort. 2000. A generalized fecal glucocorticoid assay for use in a diverse array of nondomestic mammalian and avian species. **General and Comparative Endocrinology**, 120, 260-275.
4. **Larson, S**., R. Jameson, J. Bodkin, M. Staedler and P. Bentzen. 2002. Microsatellite DNA and MtDNA variation in remnant and translocated sea otter (*Enhydra lutris*) populations. **Journal of Mammalogy** 83(3):893-906.
5. **Larson, S**., R. Jameson, M. Etnier, M. Fleming and P. Bentzen. 2002. Loss of genetic diversity in sea otters (*Enhydra lutris*) associated with the fur trade of the 18th and 19th centuries. **Molecular Ecology**. 11:1899-1903.
6. **Larson, S**., CJ Casson, and S. Wasser. 2003. Noninvasive reproductive steroid hormone estimates from fecal samples of captive female sea otters (*Enhydra lutris*). **General and Comparative Endocrinology**. 134:18-25
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American Elasmobranch Society (AES)
American Fisheries Society (AFS)
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