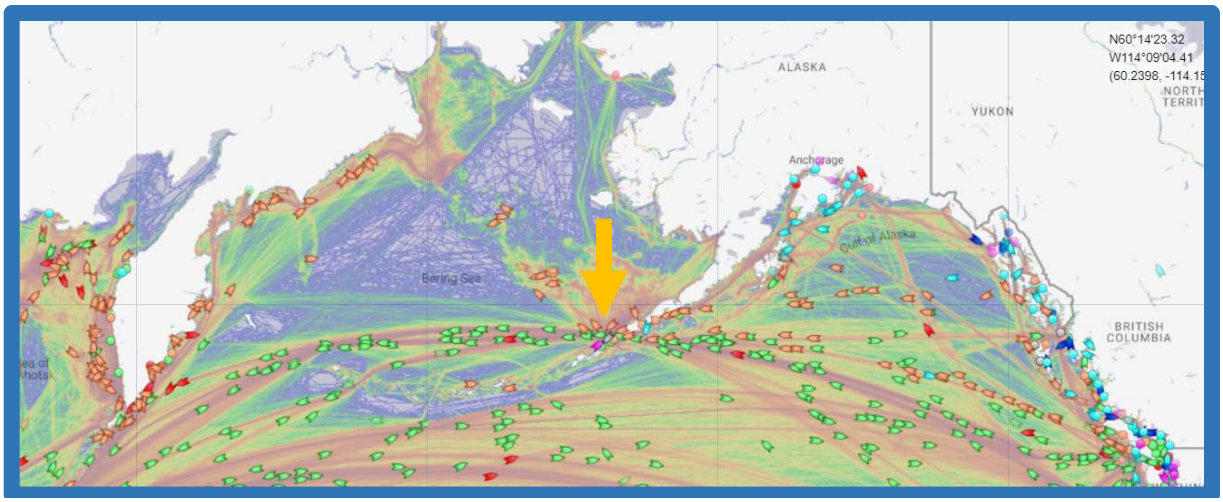

Dutch Harbor Marine Invasive Species BioBlitz

Smithsonian
Environmental Research Center

Dutch Harbor Marine Invasive Species BioBlitz

Job # 1125G.19

NOAA Award No. NA18NMF4370235

Final Report

Prepared for the
Pacific States Marine Fisheries Commission

By

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March 2020

Summary

A hotspot of shipping and fisheries activity among the Aleutians, Dutch Harbor is susceptible to impacts of both climate change, which is projected to be greatest at high latitudes, and shipping related introductions of marine non-native species. To recognize and understand ecosystem change in response to these forces, it is critical to establish measures of coastal ecosystem health that can be easily quantified and repeated. Involving the community in taking these measures strengthens local marine knowledge and ownership and builds long-term monitoring capacity.

Working with the local community in Dutch Harbor, our objectives were to:

- Assemble and build upon previous knowledge of benthic and fouling assemblages.
- Quantify change in marine fouling assemblages relative to surveys completed 15yrs ago.
- Engage the local community through schools and citizen science outreach, to raise awareness and ownership of monitoring, best management practices and control of marine invasive species.
- Cultivate local knowledge and skills for long-term monitoring capacity.

These objectives were achieved through a combination of a week-long field visit to Unalaska, followed by dedicated taxonomic and molecular scrutiny of collections made. Outreach and education events in Unalaska included public radio broadcast, a BioBlitz that was attended by members of diverse groups among the community, hands-on marine biology workshops with students from Unalaska City High School, and evening presentations that were open to the public. Field surveys for collection of invertebrate specimens included those from floating docks in the commercial and small boat harbors, coastal intertidal substrates and subtidal habitats accessed on SCUBA. Local residents were included in the collection activities focused on floating docks and subtidal habitats.

More than 200 Unalaska residents attended the education and outreach efforts. This is significant considering the population of the island is ~4,500. Among the messages delivered was the importance of citizen observers to the detection of novel introduced species in remote locations. All those attending outreach events were informed about how such detections should be reported. The interactions between students and experts in careers that are not common among the local adult population (marine biology, molecular ecology, museum curation, scientific research, wildlife biology) were considered particularly valuable.

During the surveys more than 850 specimens were collected for morphological and genetic analyses, the majority having paired tissue vouchers for deposition into the Smithsonian's Biorepository. Of these, 803 have been identified by taxonomy and or molecular sequencing. Almost 500 sequences with identifications have been uploaded to the Barcode of Life Data System (a public record). These numbers will continue to increase as additional sequences are uploaded to barcode networks, adding value to these collections.

No new non-natives were recognized during the surveys. The continued presence of the Japanese skeleton shrimp, *Caprella mutica*, was confirmed. A previous record of a species that should also be recognized as non-native is also highlighted. Continued outreach efforts will be important to the future protection of this foci among the Aleutian Islands.

Background

As the largest fisheries port in Alaska, Dutch Harbor is susceptible to shipping related introductions of non native species and the impacts of climate change, which is projected to be greatest at high latitudes (Miller and Ruiz 2014, Reimer et al. 2017). To recognize and understand ecosystem change in response to these forces, it is critical to establish measures of coastal ecosystem health that can be easily quantified and repeated. Involving the community in taking these measures strengthens local marine knowledge and ownership, and builds long-term monitoring capacity.

Fifteen years ago (2000-2003), the Smithsonian Environmental Research Center completed surveys describing marine fouling assemblages in six bays in Alaska (Ruiz et al. 2006). No non-native species were identified from Dutch Harbor during those surveys, although one was identified after the 2006 study was published (Ashton et al. 2008). Eight cryptogenic species were identified from settlement plates, including bryozoans, hydroids, and tunicates. Other surveys of subtidal habitats in Dutch Harbor include those by Jewett et al. in 2006-2007 (with site details recorded in Dasher et al. 2012), and unpublished surveys by the University of Alaska, Fairbanks. Published species records for the area are limited.

Less than 15 non-native marine species are known from coastal Alaska (de Rivera et al. 2011). While relatively few invasive species have been observed in Alaska, changes in climate and increases in vessel traffic make this area increasingly susceptible to introductions of marine species (Ruiz and Hewitt, 2009; Ware et al. 2014; Miller and Ruiz 2014). This is particularly relevant for Dutch Harbor, which was recently recognized as 'high risk' for introductions of marine non-natives via shipping (Riemer et al. 2017). Non-native species to Alaska may cause economic or environmental harm, threaten native species, and impact human health (Millennium Ecosystem Assessment 2005). Following 15 years of environmental change and potential introductions of non-native species, with no targeted surveys in the interim, it was timely to repeat a standardized survey at Dutch Harbor.

Open dialogue between scientists and the public in a BioBlitz setting is recognized as an effective approach to increase public interest in environmental research (Roger & Klistorner, 2016). In addition, citizen science initiatives have been demonstrated to support conservation both directly by having citizens on the ground responsible for site and species management, as well as indirectly through research, education and policy impacts (Mendeley et al. 2017). Local community involvement was a key aim of the current project.

Objectives

The objectives of this project were to work with the local community in Dutch Harbor to:

- Assemble and build upon previous knowledge of benthic and fouling assemblages.
- Quantify change in marine fouling assemblages relative to surveys completed 15yrs ago.
- Engage the local community through schools and citizen science outreach, to raise awareness and ownership of monitoring, best management practices and control of marine invasive species.
- Cultivate local knowledge and skills for long-term monitoring capacity.

Approach

Literature Review

A review of published and unpublished taxonomic records from Dutch Harbor was used to compile a list of species recorded from hard substrates in shallow waters (<30m) surrounding Dutch Harbor. Added to this list were unpublished reports from expert colleagues who had completed surveys of waters surrounding the Unalaska harbor. Only records that included a genus were considered in this review.

Outreach & Education

The main outreach and education goals were achieved during September 2018 when six experts from the Smithsonian Environmental Research Center, Smithsonian National Museum of Natural History and NOAA fisheries travelled to Unalaska. Outreach activities included a radio interview and an evening presentation that was open to the public. Several classes from the Dutch Harbor High School biology and fisheries classes visited the Sea Grant Laboratory where collected specimens were being processed. Students were engaged in examining specimens and question and answer interaction.

A community supported BioBlitz event, was attended by about 40 participants of all ages. Morning presentations on marine invasive species were followed by a field visit to a local dock and intertidal area to examine the Smithsonian's Plate Watch settling plates and collect intertidal organisms. Participants returned to the lab for examination and identification of collected organisms.

These activities were further leveraged by briefing a meeting of the Arctic Council's Conservation of Arctic Flora and Fauna Working Group that was meeting in the Port of Dutch Harbor/Unalaska. The group was considering issues related to the Arctic Invasive Alien Species Strategy and Action Plan.

Field Surveys

Field efforts included retrieval of settlement panels that had been deployed in the field for 3 or 12 months, benthic dive surveys, intertidal surveys, and surface water samples for eDNA (Fig. 1). Collection and preservation of material was prioritized in the field, with additional metadata and genetic samples captured when the samples returned to NMNH for curation.

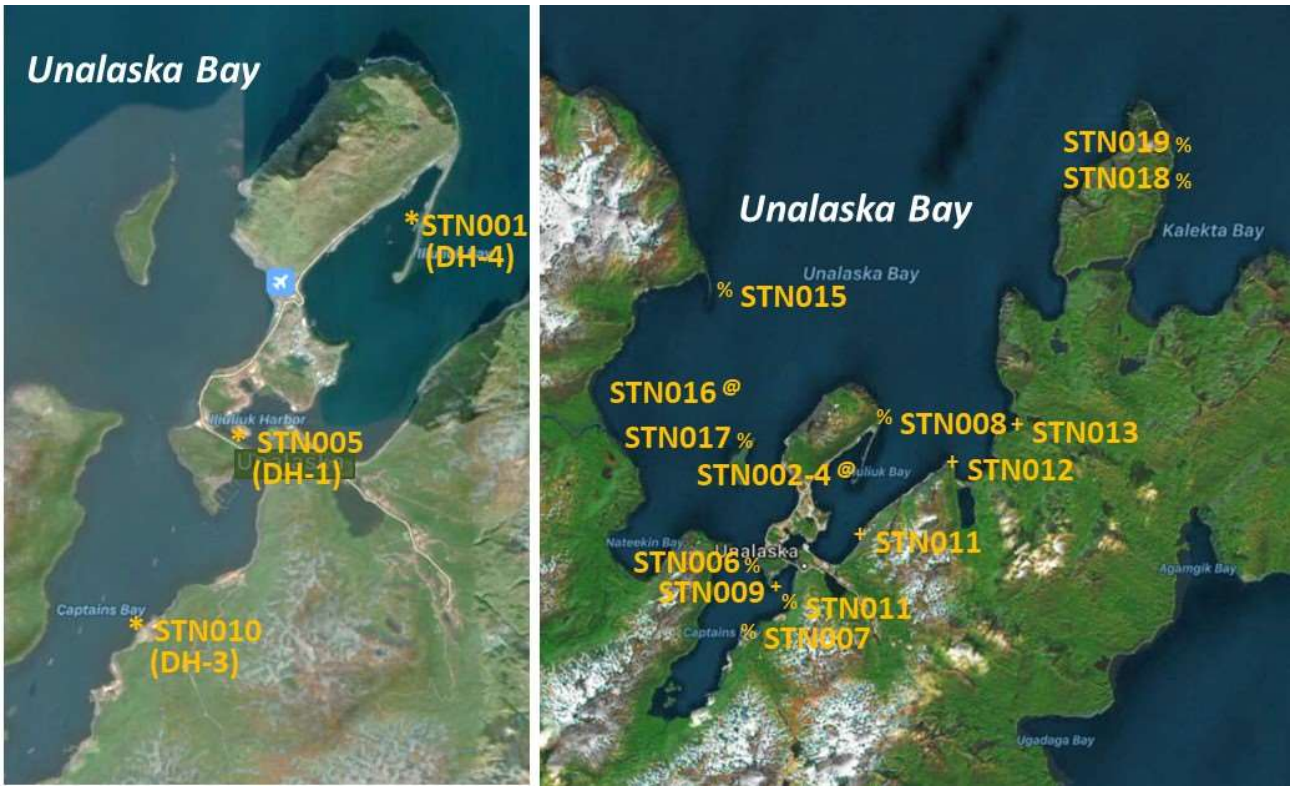


Figure 1. Location of settlement panels (left) and other collections (right) from around Dutch Harbor, Unalaska. Sites are labeled by site code from the current study and included * settlement panels, + intertidal substrates, @ surface water collections, and % subtidal substrates sampled on SCUBA. Sites from Ruiz et al. (2006) that were revisited in the current study are also labeled with previous site codes (DH-).

Forty-four settlement plates were retrieved from three harbor sites in Unalaska. Thirty-seven plates were processed live using SERC marine invasions lab standard plate processing protocols, twelve of these were then processed using the Autonomous Reef Monitoring Structure metagenetics protocol (https://naturalhistory.si.edu/research/global-arms-program). Seven plates were processed using an abbreviated SERC protocol followed by blending for metagenetics.

Three Smithsonian divers surveyed six independent sites around Dutch Harbor, Unalaska. Citizen science divers collected material from two additional locations. Intertidal collections were made at an additional three sites at low tide, three replicate plankton tows were taken in the middle of Unalaska Bay (15m depth, 1ft diameter, 64um mesh) and opportunistic collections were made from the docks at Carl Moses Harbor. Water samples were collected at the City Spit Dock (STN002-4, Fig. 1) over a series of three tidal cycles. The water was immediately passed through Sterivex 0.45um filters for eDNA.

Sample processing

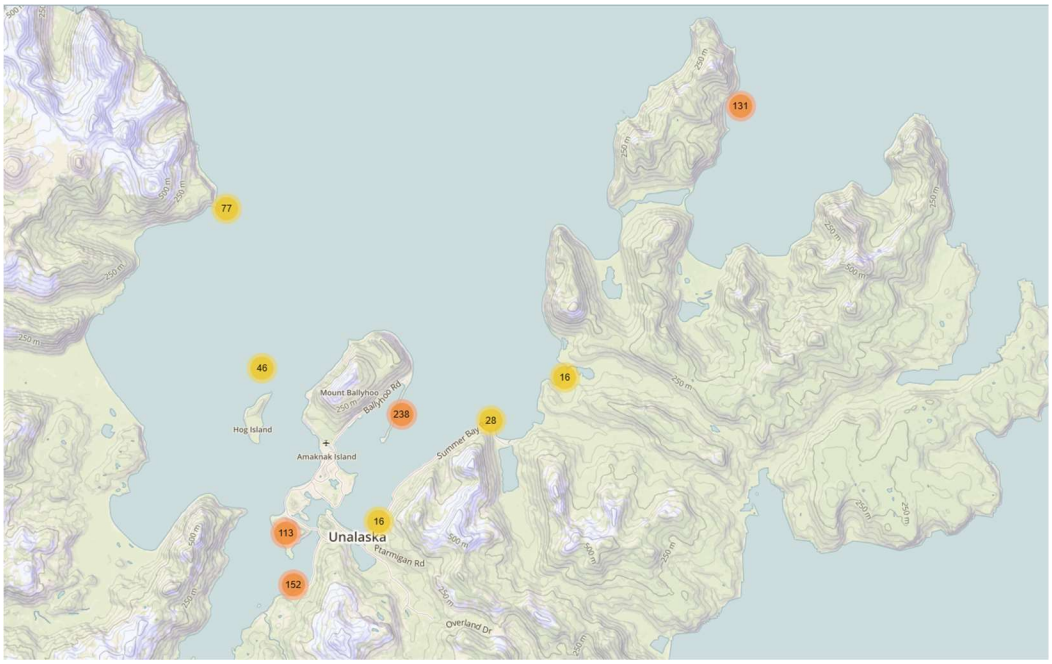
All specimens were acquisitioned into either the SERC (for specimens collected from plates) or NMNH (for all other samples) collections. Individual vouchers were sent to taxonomic experts for identification using morphological characters including H Choong (hydroids), E Keppel (polychaetes), T Gosliner (nudibranchs), G Lambert & K Larson (ascidians), L McCann (bryozoans), K Newcomer (anthozoa & cirripedia), S Pecnik (crustacea), and C Mah (echinoderms). Every effort was made to process all samples, but the funding was not secured for all processing pipelines, and data from these collections will continue to be produced in the future.

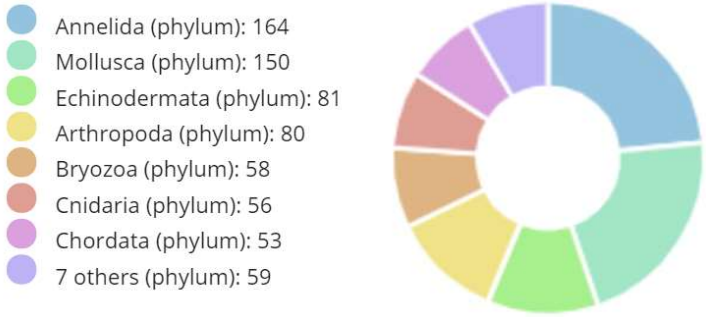
Molecular vouchers were sequenced using the jgCOI universal primer set. Where sequences failed, they were reattempted with different primer sets (& will continue to be re-visited as new technologies, methods, and time allow). The processing of metagenetic samples was not within the scope of this study.

Results

During the surveys more than 850 specimens were collected for morphological and genetic analyses, the majority having paired tissue vouchers for the Smithsonian Biorepository. Less than 20% of specimens could be assigned a genus in the field (73 genera); polychaeta and mollusca were the most diverse taxa sampled, with rare groups including brachiopoda, platyhelminthes and scyphozoa.

The identification level of the 701 matched morphological-molecular samples is shown below (e.g., 516 or 74% of the 701 specimens have been identified to Class level). A further ~100 specimens were identified from plates. At least 300 unique species were present among the specimens, 167 could be assigned species names. The taxa include members from 113 Families, 41 Orders, 20 Classes and 14 Phyla. Taxonomic foci for this report included the Annelids (284 vouchers identified by taxonomic expert), Ascidians (64), Asteroids (16), Bryozoans (75), and Hydroids (31).





	Phylum	Class	Order	Family	Genus	Species
N	701	615	583	554	503	381
%		88%	80%	79%	72%	54%

Figure 2. Location of the collection sites of specimens deposited in the Smithsonian Biorepository (top) phyletic identity of those specimens (middle) and success rate of both morphological and molecular methods to determine the identity of a specimen to each taxonomic level (bottom).

More than 427 unique invertebrate taxa have been recorded from hard substrates close to Dutch Harbor by three studies in the last 20 years. Jewett et al. (unpub.) collected 18 taxa that could be identified to genus, Ruiz et al. (2006) collected 158. The present study adds a further 257 invertebrate taxa to that list, more than doubling the total number. There were differences among the taxonomic diversity of the studies, with more annelids and bryozoans identified in the current study, and hydroids and mollusks being most diverse in Ruiz et al. 2006. Among those whose distributions could be determined, we were confident that ~90% of the species were native to the Aleutians (n=237). One non-native was identified among the specimens, the Japanese skeleton shrimp, *Caprella mutica*. In addition, the records of Jewett et al. included another non-native, the encrusting bryozoan *Schizoporella unicornis* (native to Europe). *Schizoporella japonica* has been misidentified as *S. unicornis* on the Pacific coast of North America several times, and we consider that likely to be the case here. Assuming one of these two identities is correct, the species is not native to the Aleutians and warrants further attention. The distribution of ~25 species was described as cryptogenic, largely because they belong to species complexes, the distribution of which are still being distinguished, and/or a lack of records prevents us from distinguishing historic absence. One example of this is the nudibranch *Zelentia ninel*, that has only previously been recorded from northern Norway and Russia, but whose distribution may well be pan-Arctic. It should also be noted that this species was only identified by molecular similarity, thus the identity relies on the accuracy of open access genetic records.

All data from matched morphological-molecular samples are available on the Barcode Of Life Data System: www.boldsystems.org (using search term: Dutch), and will continue to be updated as new information becomes available. E.g., the addition of matching DNA barcodes with expert identifications could add value to our own collections. Results will be combined with those expected from Job #1125V.20 in the next report.

Outcomes

- A marine invasive species BioBlitz and other community education and outreach events were held in the Port of Dutch Harbor/Unalaska, the highest risk port for marine invasive species colonization in the Bering Sea, to raise awareness, monitoring capacity and stewardship for marine invasive species prevention and management.
- The Arctic Council's Conservation of Arctic Flora and Fauna Working Group was briefed on the event as well as Alaska aquatic invasive species issues in general.
- A list of species sampled in Dutch Harbor, including molecular identifications for many species has been created. This list represents the most up-to-date and inclusive information for the harbor and can be used as a baseline/building block for future research. Importantly, data relating to specimens collected during the current project is available online via the NMNH collections database and open-access Barcode of Life Database.
- Preliminary results do not suggest any new marine invasive species in the Port of Dutch Harbor/Unalaska region. We confirm the continued presence of the Japanese skeleton shrimp, *Caprella mutica*, and the possible presence of a second non-native, *Schizoporella japonica,* which has not been recognized as non-native to date. The distribution of *Caprella mutica* is still limited to the two floating docks that it was identified from previously.

Dutch Harbor and the Aleutians more broadly, are areas of high marine biodiversity which warrant protection. Dutch Harbor is at the center of many shipping routes to and through the Bering Sea, making it at high risk from the introduction of non-native species (Reimer et al. 2017). It is somewhat surprising that only two non-native species have been recorded from the area, with no new introductions recognized since 2006. The continued absence of non-natives is supported by this study and other recent studies from the area (largely by the University of Alaska, Fairbanks). However, it may also be an indication that the sampling effort to date falls below that necessary to detect non-native species from the area. The large number of species records in the current study that had not been recorded in two previous studies may be an indication of the latter. It was also difficult to determine the status of several species as native, introduced or cryptogenic. Because the area is not well represented among open access biogeographic information systems, it is unclear whether an absence of records is a true indication of the absence of that species from the area. We were conservative in our descriptions and erred on the side of calling species native if they had been recorded previously from

anywhere in Alaska or British Columbia. In doing so, we may have misrepresented some range expansions (natural spread or human introductions) from the south.

We did not assess the citizen supported BioBlitz collections independently from those collected by scientists. Our qualitative assessment matches that of a previous study that suggested the goal of public inspiration and education was fulfilled better than the goal of collecting biodiversity information (da Silva et al. 2018). This is even more true for marine habitats than it is for terrestrial habitats since in many instances citizens have limited access into the subtidal zone. However, in remote locations where scientist-led biodiversity assessments are rare, the value of inspired citizens, and their potential to recognize change in their local habitats is considered of high value. Melissa Good already maintains a good rapport with the local students, teachers, and general public. The outreach and education efforts during the current project complemented those on-going efforts well.

Comprehensive data on the status of marine biodiversity is essential for effective marine management of marine habitats. Accurate inventory requires repeated sampling at regular intervals over time, as demonstrated by the increase in diversity provided by this study compared to Ruiz et al. 2006. Ruiz et al. were not able to sample subtidal habitats, while we did not have a hydroid or mollusk expert among our collection team.

The cost of travel to the area can be prohibitive to increased survey intensity, although local expertise, including that of local biologists and divers, could be leveraged to reduce the costs (the authors caution that taxonomic expertise of the collectors greatly enhances the diversity of resulting collections). DNA extraction from environmental samples (eDNA) is gaining popularity as a tool for monitoring marine biodiversity (Jeunen et al. 2019, Stat et al. 2017). Consistent laboratory protocols are still under development and the cost of processing eDNA samples is also still quite high. However, the eDNA samples are not expensive to collect & preserve, and we anticipate that in the future eDNA may provide a cost-effective complement to BioBlitz-style surveys. However, the results from eDNA surveys are only as strong as the genetic databases that they are compared to, thus there is a continued need for morphologically identified vouchers to be paired with sequences in open-access databases. During this project several erroneous identifications were noted in open access genetic databases and we have requested corrections in those instances. We have made a significant contribution to such biorepositories in this study and recommend that future collections are deposited in a similar way.

Acknowledgements

Funding for molecular collections was provided by the Smithsonian Institution Global Genome Initiative fund *GGI-Peer-2018-186* as well as by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, D.C., through Inter-Agency Agreement Number M14PC00003 with the Smithsonian, National Museum of Natural History, Department of Invertebrate Zoology. The work in Unalaska would not have been possible without the support of many local groups, of note were the School fisheries dept for hosting us in the husbandry facility, Qawalangin Tribe of Unalaska for their welcome & support, and the Unalaska Divers Association for SCUBA support. We would also like to thank W Moser, C Meyer and E Strong of the Department of Invertebrate Zoology for their efforts in coordinating BOEM's involvement. W Keel and S Pecnik assisted in the field and upon return of the samples to NMNH. S Jewett provided species records from dive surveys of the Aleutians in 2006-7. We are also grateful to expert taxonomists for providing voucher identifications: H Choong, M Dick, T Gosliner, E Keppel, G Lambert, K Larson, K Newcomer, C Mah, S Pecnik.

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Appendix: Identifications (at submission) of vouchers collected in Dutch Harbor during September 2018

Identities are given to the most accurate level available (and will be continued to be updated on the BOLD website as new information becomes available). Note that groups that have not been identified to Species level could include multiple species. Where species could be determined, an indication of whether the species is considered native (N), introduced (I), or cryptogenic (C) is also shown. Counts indicate the number of vouchers identified in the current study by genetic (G) or morphological (M) methods. Species records from two earlier surveys are also included in this table, indicated by a) Ruiz et al. 2006; b) Jewett et al. pers. comm.. For the latter, only data from sites close to Dutch Harbor: 21, 44, A2; were included (see Dasher et al. 2012 for site locations).

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
Annelida	Polychaeta	Eunicida	Dorvilleidae	Ophryotrocha	*Ophryotrocha* sp DH (KeppelE)		0	1	
				Dorvillea	---		0	1	
			Lumbrineridae	Lumbrinereis	---		0	2	
		Phyllodocida	Glyceridae	Glycera	*Glycera capitata*	N	0	1	
					Glycera nana	C	1	0	
			Nereididae	Nereis	*Nereis pelagica*	N	12	11	
				Nereis	*Nereis vexillosa*	N	1	2	
					---		0	1	
				Platynereis	*Platynereis bicanaliculata*	N	9	11	
			Pholoidae	Pholoe	---		1	0	
			Phyllodocidae	Eulalia	*Eulalia viridis*	N	1	0	
					Eulalia quadrioculata	N	0	12	
					---		7	1	
				Eumida	---		0	1	
				Notophyllum	*Notophyllum imbricatum*	N	0	1	
					Notophyllum tectum	C	0	2	
					---		5	0	
				Hesionidae	---		0	1	
			Polynoidae	Arctonoe	*Arctonoe pulchra*	N	0	1	
					Arctonoe vittata	N	3	1	
					Arctonoe sp.		0	1	
				Gaudichaudius	*Gaudichaudius iphionelloides*				
				Harmothoe	*Harmathoe triannulata*	C	2	2	
					Harmothoe imbricata	N	13	22	
					---		5	0	
				Malmgreniella	*Malmgreniella nigralba*	N	0	4	
				Malmgrenia	*Malmgrenia lunulata*	N	0	1	

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
				---	---		0	8	
			Spionidae	Scolelepis	---		1	0	
				Spio	---		0	2	
				---	---		0	1	
			Syllidae	Autolytinae	---		0	2	
				Epigamia	*Epigamia magna*	N	0	1	
				Proceraea	*Proceraea cornuta*	N	0	5	
					Proceraea prismatica	N	0	1	
					---		0	1	
				Syllis	*Syllis alternata*	N	1	0	
					Syllis cf. *armillaris*	N	0	3	
				Typosyllis	---		0	1	
				Trypanosyllis	---		0	3	
				---	---		0	3	
			Syllinae	---	---		0	1	
		Polychaeta	Orbiniidae	---	---		1	0	
		Sabellida	Sabellidae	Amphicorina	---		0	2	
				Bispira	---		0	1	
				Myxicola	---		0	3	
				Schizobranchia	*Schizobranchia insignis*	N	0	2	
			Serpulidae	Circeis	*Circeis armoricana*	N	---	---	a
					Circeis spirillum	N	0	1	
				Crucigera	*Crucigera zygophora*	N	0	6	
					---		0	2	
				Pseudochitinopoma	*Pseudochtinopoma occidentalis*	N	---	---	a
					---		0	1	
				Serpula	---		0	1	
				---	---		0	3	
		Terebellida	Cirratulidae	---	---		0	1	
			Terebellidae	Amphitrite	*Amphitrite cirrata*	N	6	3	
					---		---	---	
				Neoamphitrite	---		0	1	
				Polycirrus	---		0	1	
				Thelepus	*Thelepus* cf. *cincinnatus*	C	1	2	
				---	---		0	1	
		---	Capitellidae	Capitella	*Capitella capitata*	N	0	11	

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
					---		0	3	
			Chaetopteridae	Chaetopterus	---		0	2	
			Maldanidae	Nicomache	*Nicomache personata*	N	1	1	
				---	---		0	4	
			Orbinidae	Orbiniella	*Orbiniella nuda*	N	0	2	
			Oweniidae	Myriochele	*Myriochele oculata*	N	0	1	
			---	---	---		0	62	
Annelida Total							66	98	
Arthropoda	Hexanauplia	Sessilia	Archaeobalanidae	Semibalanus	*Semibalanus cariosus*	N	3	2	a
			Balanidae	Balanus	*Balanus balanus*	N	1	1	
					Balanus crenatus	N	3	12	a
					Balanus nubilus	N	1	6	b
					Balanus rostratus	N	2	2	a
					---		4	0	
	Malacostraca	Amphipoda	Ampithoidae	---	---		1	0	
			Anisogammaridae	---	---		0	1	
			Calliopiidae	---	---		1	0	
			Caprellidae	Caprella	*Caprella alaskana*	N	0	3	
					Caprella drepanochir	N	0	3	
					Caprella kennerlyi	N	0	2	
					Caprella laeviuscula	N	0	3	
					Caprella mutica	I	0	4	
				---	---		0	2	
			Ischyroceridae	Ischyrocerus	---		2	0	
			Talitridae	Megalorchestia	*Megalorchestia pugettensis*	N	1	0	
		Decapoda	Cancridae	Glebocarcinus	*Glebocarcinus oregonensis*	N	1	4	
			Cheiragonidae	Telmessus	*Telmessus cheiragonus*	N	0	1	
			Crangonidae	Argis	---		1	0	
			Epialtidae	Pugettia	*Pugettia gracilis*	N	0	3	
			Hapalogastridae	Hapalogaster	*Hapalogaster mertensii*	N	1	0	
					---		0	1	
			Lithodidae	Cryptolithodes	---		0	1	
				Paralithodes	*Paralithodes camtschaticus*	N	0	2	
				Rhinolithodes	*Rhinolithodes wosnessenskii*	N	0	1	
			Oregoniidae	Hyas	*Hyas lyratus*	N	0	1	
			Paguridae	Elassochirus	*Elassochirus gilli*	N	0	1	
					Elassochirus tenuimanus	N	0	3	

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
				Pagurus	*Pagurus beringanus*	N	1	0	
					Pagurus hirsutiusculus	N	0	1	
					Pagurus kennerlyi	N	1	0	
				---	---		1	1	
			Thoridae	Heptacarpus	*Heptacarpus brevirostris*	N	0	2	
					Heptacarpus carinatus	N	0	1	
					Heptacarpus paludicola	N	0	1	
					---		2	3	
		Isopoda	Idoteidae	Idotea	---		0	2	
				Pentidotea	*Pentidotea wosnesenskii*	N	5	1	
			Ligiidae	Ligia	*Ligia pallasii*	N	0	1	
		Mysida	Mysidae	Archaeomysis	---		1	0	
		Tanaidacea	---	---	---		0	1	
	---	---	---	---	---		0	15	
Arthropoda Total							18	58	
Brachiopoda	Rhynchonellata	Rhynchonellida	Hemithirididae	Hemithiris	*Hemithiris psittacea*	N	0	1	
		---	---	---	---		0	1	
Brachiopoda Total							0	1	
Bryozoa	Gymnolaemata	Cheilostomatida	Beaniidae	Beania	---		0	2	
			Bryocryptellidae	Porella	---		0	1	
			Bugulidae	Bugula	*Bugula californica*	N	0	1	
				Crisularia	*Crisularia pacifica*	N	---	---	a
				Corynoporella	*Corynoporella spinosa*	N	0	1	
				Dendrobeania	*Dendrobeania* cf. *multiseriata*	N	0	1	
					Dendrobeania murrayana	N	0	5	
			Calloporidae	Callopora	---		---	---	a
				Caularamphus	---		---	---	a
				Tegella	*Tegella* cf. *armifera*	N	---	---	a
					Tegella aquilirostris	N	0	1	a
				---	---		0	10	
			Candidae	Tricellaria	*Tricellaria circumternata*	N	0	1	
					---		0	3	
			Celleporidae	Celleporina	---		0	3	
			Cryptosulidae	Cryptosula	*Cryptosula zavjalovensis*	N	0	1	
			Doryporellidae	---	---		0	2	
			Electridae	Einhornia	*Einhornia crustulenta*	C	0	3	
			Eurystomellidae	Intagripelta	*Intagripelta bilabiata*	N	0	1	

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
			Fatkullinidae	Stomacrustula	Cf. *Stomacrustula limbata*	N	0	1	
			Flustrina	Cribrilina	*Cribrilina corbicula*	N	---	---	a
			Hippothoidae	Celleporella	*Celleporella hyalina*	C	0	5	
			Membraniporidae	Membranipora	*Membranipora villosa*	N	0	4	a
					---		1	0	
			Microporellidae	Fenestrulina	---		0	1	
			Microporidae	Microporina	*Microporina articulata*	N	0	6	b
			Myriaporidae	Leieschara	*Leieschara coarctata*	N	0	2	
				Myriozoella	*Myriozoella* cf. *plana*	N	0	1	
				---	---		0	2	
			Schizoporellidae	Schizoporella	*Schizoporella japonica*	I	---	---	b
			Smittinidae	Phylactella	*Phylactella pacifica*	N	0	1	
				Schizomavella	*Schizomavella porifera*	N	0	1	
			Umbonulidae	Rhamphostomella	*Rhamphostomella gigantia*	N	0	2	
					Rhamphostomella sp1		0	2	
			---	---	---		4	0	
		Ctenostomata	Alcyonidiidae	Alcyonidium	*Alcyonidium pedunculatum*	N	0	1	
					Alcyonidium sp 1 (McCannL)		0	3	
					Alcyonidium sp 3 (McCannL)		0	2	
					Alcyonidium sp 4 (McCannL)		0	1	
					---		---	---	a
			Flustrellidridae	Flustrellidra			0	4	
	Stemolaemata	Cyclostomata	Articulina	Crisiella	---		---	---	a
			Lichenoporidae	Patinella	*Patinella verrucaria*	N	0	1	a
				---	---		0	3	
			---	---	---		0	2	
	---	---	---	---	---		0	113	
Bryozoa Total							5	55	
Chordata	Ascidiacea	Aplousobranchia	Didemnidae	Didemnum	*Didemnum albidum*	N	0	3	
				Trididemnum	*Trididemnum alexi*	N	0	2	
				---	---		1	1	
			Holozoidae	Distaplia	*Distaplia alaskensis*	N	---	---	a
					Distaplia occidentalis	N	0	3	a
					Distaplia smithi	N	0	2	
					---		0	1	
			Polyclinidae	Aplidium	*Aplidium californicum*	N	0	9	
					Aplidium coei	N	0	2	

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
					Aplidium spitzbergense	N	0	1	
					---		1	0	
				Synoicum	*Synoicum* cf *kincaidi*	C	0	1	
			---	---	---		2	0	
		Stolidobranchia	Molgulidae	Molgula	---		---	---	a
			Phlebobranchia	Ascidia	*Ascidia callosa*	N	---	---	a
					Ascidia columbiana	N	---	---	a
			Pyuridae	Halocynthia	*Halocynthia aurantium*	N	0	3	b
			Styelidae	Botryllus	*Botryllus magnus*	N	0	3	
					---		0	1	
				Dendrodoa	*Dendrodoa aggregata*	N	0	2	
				Styela	*Styela truncata*	N	0	4	
					Styela yakutatensis	N	0	2	
				---	---		2	24	
Chordata Total							9	45	
Cnidaria	Anthozoa	Actiniaria	Actiniidae	Anthopleura	*Anthopleura elegantissima*	N	---	---	a
					Anthopleura xanthogrammica	N	---	---	a
				Cribrinopsis	*Cribrinopsis* cf. *fernaldi*	N	0	1	
				Epiactis	---		2	0	
				Urticina	*Urticina columbiana*	N	---	---	a
					Urticina crassicornis	N	0	2	a
					Urticina sp. AAI5336		1	0	
					---		3	2	
			Metridiidae	Metridium	*Metridium senile*	N	7	0	a
		Alcyonacea	---	---	---		0	2	
	Hydrozoa	Anthoathecata	Bougainvilliidae	Bougainvillia	*Bougainvillia* cf. *superciliaris*	C	---	---	a
					Bougainvillia principis	N	---	---	a
			Capitata	Polyorchis	*Polyorchis penicillatus*	N	---	---	a
			Corynidae	Sarsia	*Sarsia tubulosa*	N	0	1	
					Sarsia sp. B		---	---	a
			Proboscidactylidae	Proboscidactyla	*Proboscidactyla flavicirrata*	N	---	---	a
			Pandeidae	Leuckartiara	*Leuckartiara* cf. *foersteri*		---	---	a
				Stomotoca	*Stomotoca atra*	N	---	---	a
		Leptothecata	Aequoreidae	Aequorea	*Aequorea Aequorea v. Aequorea*	N	---	---	a
					Aequorea Aequorea v. albida	N	---	---	a

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
							0	2	
				Obelia	*Obelia dichotoma*	C	2	9	a
					Obelia geniculata	C	---	---	a
					Obelia longissima	C	0	2	a
			Campanulariidae	Clytia	*Clytia gregaria*	C	---	---	a
					Clytia hemisphaerica	C	---	---	a
				Gonothyraea	*Gonothyraea clarki*	C	---	---	a
					Gonothyraea loveni	C	0	3	
				Laomedea	*Laomedea exigua*	C	---	---	a
				Orthopyxis	*Orthopyxis caliculata*	C	---	---	a
			Campanulinidae	Calycella	*Calycella syringa*	C	0	1	a
				Cuspidella	*Cuspidella grandis*	N	---	---	a
					Cuspidella humilis	N	---	---	a
				Opercularella	*Opercularella lacerata*	C	---	---	a
			Dipleurosomatidae	Dipleurosoma	*Dipleurosoma typicum*	N	---	---	a
			Eirenidae	Eutonina	*Eutonina indicans*	N	---	---	a
			Lafoeidae	Filellum	*Filellum serratum*	C	0	1	
			Laodiceidae	Staerphora	*Staurophora mertensi*	N	---	---	a
			Melicertidae	Melicertum	*Melicertum octocostatum*	N	---	---	a
			Mitricomidae	Mitrocoma	*Mitrocoma cellularia*	N	---	---	a
			Sertularellidae	Sertularella	*Sertularella elegans*	N	---	---	a
					Sertularella rugosa	N	---	---	a
			Sertulariidae	Abietinaria	*Abietinaria amphora*	N	---	---	a
					Abietinaria annulata	N	0	1	
					Abietinaria turgida	N	0	2	a
					Abietinaria variabilis	N	0	4	
				Sertularia	*Sertularia robusta*	N	---	---	a
					---		0	2	
				Thuiaria	*Thuiaria dalli*	N	---	---	a
				---	---		0	3	
			---	---	---		1	0	
		Limnomedusae	Olindiidae	Eperetmus	*Eperetmus typus*	N	---	---	a
			---	---	---		1	0	
		Siphonophorae	Agalmatidae	Agalma	*Agalma elegans*	N	---	---	a
		Trachymedusae	Rhopalonematidae	Aglantha	*Aglantha digitale*	N	---	---	a
	Scyphozoa	Semaeostomeae	Cyanidae	Cyanea	*Cyanea ambiguum*	N	---	---	a
			Ulmaridae	Aurelia	*Aurelia labiata*	N	---	---	a

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
	Staurozoa	Stauromedusae	Haliclystidae	Haliclystus	*Haliclystus auricula*	N	---	---	a
		---	---	---	---		1	17	
Cnidaria Total							16	40	
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Evasterias	*Evasterias troschelii*	N	6	0	b
				Leptasterias	*Leptasterias alaskensis*	N	1	0	b
					Leptasterias hexactis	N	3	2	
					Leptasterias leptodoma	N	1	1	
					---		1	4	
				Orthasterias	*Orthasterias koehleri*	N	1	1	
		Spinulosida	Echinasteridae	Henricia	*Henricia oculata*	C	1	1	
					---		5	1	b
			---	---	---		1	0	
		Valvatida	Goniasteridae	Mediaster	*Mediaster aequalis*	N	1	1	
			Solasteridae	Crossaster	*Crossaster papposus*	N	3	2	
				Solaster	*Solaster stimpsoni*	N	2	0	
		Velatida	Pterasteridae	Pteraster	*Pteraster tesselatus*	N	2	2	
					Pteraster sp. AAH7925		1	1	
	Echinoidea	Clypeasteroida	Echinarachniidae	Echinarachnius	*Echinarachnius parma*	C	---	---	b
		Echinoida	Strongylocentrotidae	Strongylocentrotus	*Strongylocentrotus droebachiensis*	N	7	0	b
					Strongylocentrotus pallidus	N	0	0	
	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	*Cucumaria miniata*	N	4	2	
			Sclerodactylidae	Eupentacta	---		5	2	
	Ophiuroidea	Ophiurida	Amphiuridae	Amphipholis	*Amphipholis squamata*	N	2	1	
					---		4	0	
			Ophiactidae	Ophiopholis	*Ophiopholis aculeata*	N	6	4	
					Ophiopholis kennerlyi	N	9	5	
					---		1	1	
	---	---	---	---	---		0	37	
Echinodermata Total							38	39	
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Hiatella	*Hiatella arctica*	N	0	4	a
					---		0	2	
		Anomalodesmata	Thraciidae	Thracia	*Thracia myopsis*	N	---	---	a
					---		---	---	a
		Cardiida	Cardiidae	Clinocardium	*Clinocardium californiense*	N	---	---	a
					Clinocardium ciliatum	N	---	---	a

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
					Clinocardium nuttallii	N	---	---	a
				Serripes	*Serripes groenlandicus*	N	---	---	a
			Tellinidae	Macoma	*Macoma balthica*	N	---	---	a,b
					Macoma brota	N	---	---	a
					Macoma calcarea	N	---	---	a
					Macoma carlottensis	N	---	---	a
					Macoma golikovi	N	---	---	a
					Macoma inquinata	N	---	---	a
					Macoma moesta moesta	N	---	---	a
				Tellina	*Tellina lutea*	N	---	---	a
		Galeommatida	Lasaeidae	Kellia	*Kellia suborbicularia*	N	---	---	a
				Mysella	---		---	---	a
				Rochefortia	*Rochefortia tumida*	N	---	---	a
		Lucinida	Thyasiridae	Thyasira	*Thyasira flexuosa*	N	---	---	a
					---		---	---	a
		Myida	Myidae	Mya	*Mya pseudoarenaria*	N	---	---	a
					Mya truncata	N	---	---	a
					---		---	---	a
				---	---		0	1	
		Mytilida	Mytilidae	Crenella	*Crenella decussata*	N	---	---	a
				Modiolus	*Modiolus modiolus*	N	2	0	a
					---		0	1	
				Mytilus	*Mytilus trossulus*	N	9	1	a
					---		0	2	a
				Musculus	*Musculus discors*	N	---	---	a
					Musculus niger	N	---	---	a
		Nuculanida	Nuculanidae	Nuculana	*Nuculana pernula*	N	---	---	a
					---		---	---	a
			Tindariidae	Tindaria	---		---	---	a
			Yoldiidae	Yoldia	*Yoldia thraeciaformis*	N	---	---	a
				Yoldiella			---	---	a
		Nuculida	Nuculidae	Ennucula	*Ennucula tenuis*	N	---	---	a
		Pectinida	Anomiidae	Pododesmus	*Pododesmus macrochisma*	N	---	---	a
					---		0	1	
				---	---		1	0	
			Pectinidae	Pecten	---		0	1	
		Venerida	Mactridae	Mactromeris	*Mactromeris polynyma*	N	---	---	a,b

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
			Ungulinidae	Diplodonta	*Diplodonta aleutica*	N	---	---	a
			Veneridae	Nutricola	*Nutricola lordi*	N	---	---	a
				Protothaca	*Protothaca staminea*	N	---	---	a
				Saxidomus	*Saxidomus gigantea*	N	---	---	a
				Turtonia	*Turtonia minuta*	N	---	---	a
		---	---	---	---		0	1	
	Gastropoda	Archaeogastropoda	Margaritidae	Margarites	*Margarites beringensis*	N	---	---	a
					Margarites pupillus	N	5	0	a
					---		1	0	
		Cephalaspidae	Retusidae	Retusa	---		---	---	a
		Lepetellida	Fissurellidae	Puncturella	*Puncturella multistriata*	N	---	---	b
				---	---		0	1	
		Littorinimorpha	Capulidae	Ariadnaria	*Ariadnaria insignis*	N	2	0	a
			Eulimidae	Balcis	*Balcis alaskensis*	N	---	---	a
				Melanella	*Melanella randolphi*	N	---	---	a
			Littorinidae	Lacuna	*Lacuna vincta*	N	3	5	a
					---		0	2	a
				Littorina	*Littorina sitkana*	N	---	---	a
			Naticidae	Cryptonatica	*Cryptonatica affinis*	N	---	---	a
					Cryptonatica aleutica	N	---	---	b
			Ranellidae	Fusitriton	*Fusitriton oregonensis*	N	2	0	a,b
				---	---		2	0	
			Rissoidae	Cingula	*Cingula aleutica*	N	---	---	a
					---		---	---	a
				---	---		---	---	a
			Velutinidae	Marsenina	---		0	1	
				Velutina	*Velutina velutina*	N	0	1	
					---		---	---	a
			---	---	---		0	1	
		Neogastropoda	Buccinidae	Buccinum	*Buccinum baeri*	N	---	---	a
					Buccinum plectrum	N	---	---	a
					---		3	0	
				Neptunea	*Neptunea pribiloffensis*	N	---	---	a
					Neptunea ventricosa	N	---	---	a
				Volutharpa	*Volutharpa ampullacea*	N	---	---	a
			Columbellidae	Amphissa	*Amphissa columbiana*	N	5	0	a,b
				Astyris	*Astyris rosacea*	N	---	---	a

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
			Mangaliidae	Oenopota	---		---	---	a
			Muricidae	Boreotrophon	---		---	---	a
				Trophonopsis	---		---	---	a
				Nucella	*Nucella canaliculata*	N	1	1	a
					Nucella lamellosa	N	2	0	
					Nucella lima	N	---	---	a
					---		1	0	
				Scabrotrophon	*Scabrotrophon maltzani*	N	1	0	
		Nudibranchia	Cadlinidae	Cadlina	*Cadlina modesta*	N	0	1	
			Dendronotidae	Dendronotus	*Dendronotus frondosus*	N	---	---	a
					Dendronotus venustus	N	1	1	
					Dendronotus subramosus	N	0	1	
					---		0	2	
			Discodorididae	Diaulula	*Diaulula odonoghuei*	N	0	1	
					Diaulula sandiegensis	N	---	---	a,b
				Doris	*Doris montereyensis*	N	2	0	b
				Peltodoris	*Peltodoris nobilis*	N	1	1	
			Eubranchidae	Eubranchus	*Eubranchus olivaceus*	N	0	2	
					Eubranchus rupium	N	---	---	a
			Facelinidae	Hermissenda	*Hermissenda crassicornis*	N	0	2	
					---		0	1	
			Fionidae	Cuthona	---	N	---	---	a
				Cuthonella	*Cuthonella concinna*	N	0	1	
			Flabellinidae	Flabellina	*Flabellina fusca*	N	0	1	
					Flabellina trophina	N	---	---	a
			Goniodoridae	Ancula	*Ancula pacifica*	N	0	1	
			Onchidorididae	Adalaria	*Adalaria proxima*	N	2	2	
				Onchidoris	*Onchidoris bilamellata*	N	2	5	a
					Onchidoris muricata	N	0	2	a
			Polyceridae	Triopha	*Triopha catalinae*	N	1	2	
					---		0	1	
			Proctonotidae	Janolus	*Janolus fuscus*	N	1	1	
			Trinchesiidae	Zelentia	*Zelentia ninel*	C	1	0	
				---	---		1	0	
			---	---	---		1	0	
		Patellogastropoda	Acmaeidae	Acmaea	*Acmaea mitra*	N	3	2	
					---		0	1	a

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
			Lepetidae	Lepeta	*Lepeta concentrica*	N	2	1	a
					---		---	---	a
			Lottiidae	Collisella	---		---	---	a
				Lottia	*Lottia* cf. *borealis*	N	---	---	a
					Lottia pelta	N	---	---	a
					Lottia scutum	N	5	1	a,b
					---		3	1	
				Niveotectura	*Niveotectura funiculata*	N	0	1	
		Pylopulmonata	Pyramidellidae	Odostomia	---		---	---	a
		Sacoglossa	Stiligeridae	Placida	*Placida dendritica*	C	0	2	
		Siphonariida	Siphonariidae	Siphonaria	*Siphonaria thirsites*	N	---	---	a
		Trochida	Colloniidae	Moelleria	*Moelleria quadrae*	N	---	---	a
			Solariellidae	Solariella	*Solariella obscura*	N	---	---	a,b
	Polyplacophora	Chitonida	Ischnochitonidae	Stenosemus	*Stenosemus albus*	N	1	1	
			Mopaliidae	Katharina	*Katharina tunicata*	N	0	2	a
				Mopalia	*Mopalia ciliata*	N	---	---	a
					Mopalia hindsii	N	---	---	a
					Mopalia kennerlyi	N	2	3	a
					---		2	0	
			Tonicellidae	Tonicella	*Tonicella insignis*	N	3	3	
					Tonicella lineata	N	9	6	a
			Schizoplacidae	Schizoplax	*Schizoplax brandtii*	N	---	---	a
			---	---	---		0	4	
		Lepidopleurida	Leptochitonidae	Leptochiton	*Leptochiton alascensis*	N	1	1	
				Spongioradsia	*Spongioradsia aleutica*	N	---	---	a
		---	---	---	---		0	30	
Mollusca Total							39	105	
Nemertea	Hoplonemertea	Monostilifera	Amphiporidae	Amphiporus	*Amphiporus imparispinosus*	N	1	0	
				Zygonemertes	---		1	0	
			Emplectonematidae	Emplectonema	---		2	0	
				Paranemertes	*Paranemertes* sp. BDG-M2		1	0	
			---	---	---		5	0	
	Palaeonemertea	---	Cephalothricidae	Cephalothrix	*Cephalothrix spiralis*	N	1	0	
		---	Tubulanidae	Tubulanus	---		0	1	
	Pilidiophora	Heternemertea	Lineidae	Lineus	*Lineus flavescens*	N	1	0	
				Kulikovia	*Kulikovia* cf. *torquatus*	N	0	3	
	---	---	---	---	---		0	11	

Phylum	Class	Order	Family	Genus	Species	INC	G	M	ab
Nemertea Total							6	12	
Platyhelminthes	Rhabditophora	Polycladida	---	---	---		3	0	
	---	---	---	---	---		0	5	
Platyhelminthes Total							3	5	
Porifera	Demospongiae	Hadromerida	Polymastiidae	Polymastia	---		1	1	
				---	---		1	0	
			Tethyidae	Tethya	---		0	1	
		Spirophorida	Tetillidae	Craniella	---		0	1	
		Suberitida	Suberitidae	Suberites	---		1	0	
			Halichondriidae	Halichondria	*Halichondria panicea*	C	1	0	
					---		1	0	
		---	---	---	---		1	19	
Porifera Total							3	23	
Sipuncula	---	---	---	---	---		0	1	
Sipuncula Total							0	1	
Xenacoelomorpha	---	---	---	---	---		0	2	
Xenacoelomorpha Total							0	2	
					Count from this study			**267**	
					Count from Ruiz et al. 2006			**158**	
					Count from Dasher et al. 2012			**18**	
					Total across all 3 studies			**436**	

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