North Pacific Marine Science Organization (PICES)
PICES-MoE project on "*Effects of marine debris caused by the Great Tsunami of 2011*"
Year 3 Final Scientific Report

1. PROJECT INFORMATION

Title	**Biological sampling and characterization of JTMD**
Award period	**April 1, 2016 – March 31, 2017**
Amount of funding	**$15,360**
Report submission date	**January 31, 2017**
Lead Author of Report*	**John W. Chapman**

**Although there may be only one lead author of the report, all PIs and co-PIs of the project, as identified in the approved statement of work and listed below, are responsible for the content of the Final Report in terms of completeness and accuracy.*

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2. YEAR 3 PROGRESS SUMMARY

Briefly describe your progress and challenges during Year 3 of the project, specifically.

a. **Describe progress.**

Biological sampling of JTMD

Year 3 — April 1, 2016 to January 31, 2017

We sampled all available JTMD objects arriving on the Oregon and Washington coasts. These JTMD objects were collected directly, or intercepted in cooperation with private individuals and the personnel of non-profit, county, state and federal agencies. Only a minor fraction of all arriving debris were possible to sample. Nevertheless, more than 30 trips were made under year 3 funding to intercept JTMD objects that ranged in size from derelict boats to minor household or industrial items (see Carlton et al. JTMD Master Register). Many more objects were processed for JTMD verification than proved to be JTMD. All verified JTMD objects were photographed, measured and searched for associated organisms. Large organisms, including acorn barnacles, bivalves and encrusting hydroids and bryozoan colonies were removed separately and frozen or preserved in 95% ETOH. Scrape samples were also collected and frozen or preserved in 95% ETOH. Nearly all processing of these samples was completed at the Maritime Studies Program of Williams College and Mystic Seaport in Mystic CT. Peracaridan crustaceans were returned to OSU for taxonomic and morphological analyses. Analyses and summaries of year 1 and 2 samples and data for publication continued.

b. Describe any concerns or challenges you may have about your project's progress.

A majority of JTMD arrives between March and June, coincident with strong, persistent south winds and inclement weather. JTMD deposition on ocean shores occurs at high tide during in inclement weather while observers discover most JTMD during low tide access and in fair weather conditions. A majority of JTMD is consequently, discovered days or weeks after landing. Organisms recovered from JTMD are therefore commonly in poor condition and lacking large numbers of the associated populations that were lost in the violent surf conditions during the on-shore deposition. The taxonomy of JTMD species requires analyses of damaged and less than perfectly preserved material. Re-analyses of the samples improves the accuracy and precision of JTMD species taxonomy.

3. ABSTRACT

Transoceanic colonization of species on passively drifting objects has been a widely invoked, and undocumented explanation of disjunct marine species distributions that span oceans and continents. Reproductive, non-native marine western Pacific peracaridan crustaceans (including gammarid and caprellid amphipods, isopods, and tanaids) with drifting objects generated by the Great Japanese Tsunami of 11 March 2011 began to arrive on eastern Pacific shores in June 2012. These landfalls of Asian species on JTMD have continued since. Many Asian species have survived the North Pacific transit on JTMD as due to their long lives. Short-lived species can only survive multi-year open ocean crossings on JTMD by replacement. We surveyed for peracaridan crustaceans from JTMD objects arriving on the Oregon and Washington coasts to assess their potentials for self-replacement and also their diversities, relative abundances and geographical origins.

4. PROJECT DESCRIPTION

Biological Characterization of JTMD peracaridan crustaceans:

Year 1 PICES funds supported image analyses of small crustacean popualations, analyses of JTMD abundance and composition and aerial/vessel search and recovery assessments.

Year 2 PICES funds supported collection and processing of incoming JTMD, curation of incoming biological collections, online debris and biological catalogue, coordination of sample distribution and assistance with JTMD wood survey (Nancy Trenamen) and continued assessments of species survival, population growth, and reproductive condition focused largely on selected crustacean taxa.

Year 3 PICES funds supported collection and processing of incoming JTMD, curation of incoming biological collections, online debris and biological catalogue, coordination of sample distribution.

a) Research Purpose

This research supported characterization of the biodiversity, reproductive status and biology of alien crustacean species on Japanese Tsunami Marine Debris (JTMD) generated on March 11, 2011 by the Great East Japan Earthquake. A fundamental rationale of JTMD characterization research has been to resolve the invasion potential of non-indigenous species arriving on JTMD. Major parameters required for such risk assessment include the diversity, reproductive potential, biology and ecology of Japanese species on JTMD that arrive on North American and Hawaiian shores. Surviving mussels, *Mytilus galloprovincialis* and barnacles, *Megabalanus rosa* and *Semibalanus cariosus*, that settled on JTMD following the tsunami event, or that were present on the JTMD at the time of the event, continue to arrive on North American shores. These species survive without replacement. The continued arrivals of these species since 2012 provide a foundation for assessing the types of organisms that are particularly robust and have high invasive potential. Short-lived peracaridan crustaceans survived ocean crossings on the same JTMD objects and the long-lived species. These small crustaceans survived by self-replacement. Knowledge of how these organisms completed entire life cycles during the open ocean crossings thus provides an additional foundation for assessing the risks of alien species.

Research on open ocean crossings of coastal Asian species on passively drifting objects began on 5 June 2012, with the appearance of a heavily fouled, 188 tonne dock from the Misawa fishing port of Japan on Nye Beach, Oregon. Previous information on nearshore shallow-water marine Asian species surviving open ocean crossings by passive drift on marine debris was all but absent. All JTMD was launched in a few minutes in the course of the catastrophic event. Populations of the short-lived peracaridan species initially occurring or settling on these objects drifted away from the coastal waters of Japan into the 40 million km^2 area of the North Pacific on their passage to North America. These drifting populations survived for multiple years on these drifting objects by self-recruitment. Potentials for cross recruitment among JTMD objects at sea could only have been remote. High potentials for species extinctions or genetic bottlenecks the JTMD populations reaching North America and Hawaii were expected.

This report includes peracaridan crustaceans collected from of fouling assemblages on floating debris, such as docks, boats, pallets, household objects, baskets and trays that drifted across the Pacific Ocean from northern Japan to the west coast of the United States following the Tōhoku earthquake and tsunami.

b) Objectives

- **a.** Measure the diversity and frequency of alien peracaridan crustacean species arriving on JTMD.
- **b.** Measure population structures and trophic responses of peracaridan crustacean species arriving on JTMD.

c. Estimate the abundance, diversity, composition and ocean persistence of peracaridan crustaceans arriving JTMD

d. Estimate the abundance and diversity of JTMD.

c) Methods

More than 100 trips were made to intercept JTMD objects directly or to receive from private individuals, non-profit, local, state and federal agencies. These JTMD objects ranged in size from derelict boats to household or industrial items (see Carlton et al. JTMD Master Register). All JTMD objects were photographed, measured and inspected for associated organisms. Large organisms, including acorn barnacles, bivalves and encrusting hydroids and bryozoan colonies were removed separately and frozen or preserved in 95% ETOH. Scrape samples were also collected and frozen or preserved in 95% ETOH. The role final processing of these samples was completed at the Maritime Studies Program of Williams College and Mystic Seaport in Mystic CT. Peracaridan crustaceans were returned to OSU for taxonomic and morphological analyses.

We assessed species abundances and population structure with year 1 and 2 funds. Fro these analyses, we sorted sample populations by reproductive development (juveniles and mature) and by sex and used image analyses to measure structures lengths. We calibrated digital image measures were calibrated by repeated measures, using a calibrated microscope and by redundant measures of the images. Our survey of JTMD wood was to partially assess biologic risks of JTMD species and also to assess JTMD abundances and mass. We surveyed the size frequencies and reproductive conditions of arriving peracaridan crustaceans to assess the ocean survival and invasion potential of short-lived JTMD species. We conducted areal and vessel ocean surveys to test the efficacy of ocean interceptions of debris and to partially assess thte JTMD abundance and mass by an alternative method to beached wood surveys. We surveyed JTMD from a systematic beach cleaning effort to expand JTMD sampling diversity and to provide a third method for estimating JTMD diversity and abundance. We analysed the taxonomy of JTMD peracaridan crustaceans to partially measure the potential of JTMD as a mechanism for transporting unique Asian species to North America with potential to establish new and persistent populations.

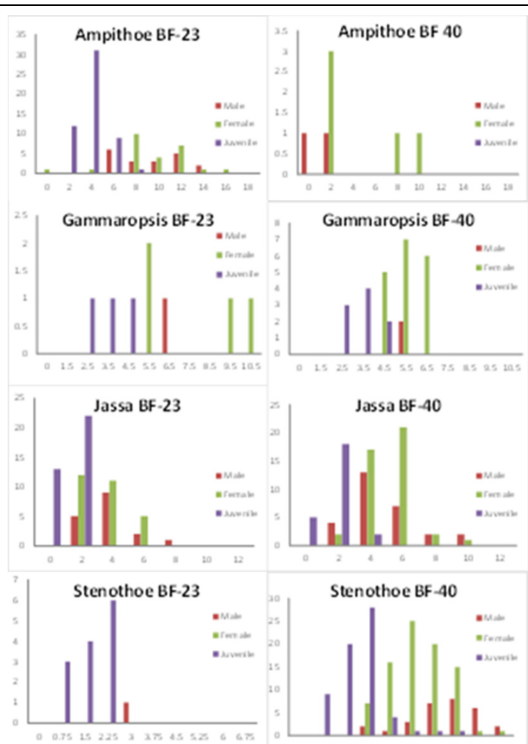


Figure 1. Length frequencies of male, female and juvenile *Ampithoe*, *Gammaropsis*, *Jassa* and *Stenothoe* from JTMD objects BF-23 and BF-40

We estimated the abundance and diversity of biofouled JTMD by gross surveys of beach lumber, by aerial and vessel surveys of the coastal ocean for JTMD and by analysis of debris gathered in a long term comprehensive beach cleaning effort.

d) Results

Crustacean population structure and reproductive development

John Chapman (OSU)

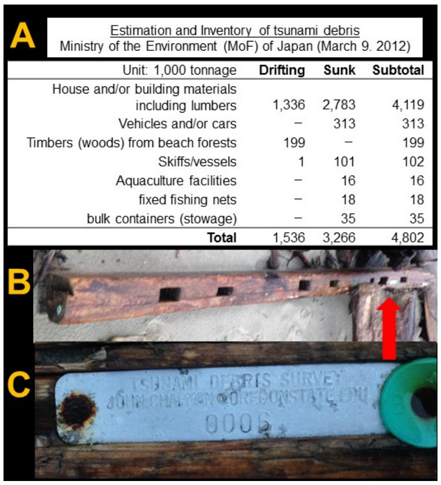
The size frequencies of these crustaceans revealed multiple overlapping cohorts within sexes (Figure 1). Single specimens from individual objects were unsuited for size analyses. However, we did not find large populations lacking in either juveniles or reproductive adults. Recent trophic conditions surrounding the JTMD objects appear to have been suitable for long term persistence. However, in example, the general differences (Figure 1) between items BF-23 (a Japanese vessel that landed in Oregon in February 2013) and BF-40 (a vessel that landed in Washington in March 2013) indicate that the recent history of BF-23 included less time in high trophic availability conditions than BF-40.

Although size frequencies and frequencies of reproductive stages varied, all populations were reproductive. We did not find predominantly mature but non-reproductive peracatidan populations. Peracaridan crustaceans could have restricted reproduction and survival on most JTMD objects. However, the populations surviving ocean crossing could have high potential to invade North American ecosystems.

JTMD Abundance

Beach Survey and Monitoring of JTMD Post-and-Beam Japanese Building Wood

John Chapman (OSU) (with Nancy Treneman, Gold Beach)



Estimation and Inventory of tsunami debris
Ministry of the Environment (MoF) of Japan (March 9. 2012)

Unit: 1,000 tonnage	Drifting	Sunk	Subtotal
House and/or building materials including lumbers	1,336	2,783	4,119
Vehicles and/or cars	–	313	313
Timbers (woods) from beach forests	199	–	199
Skiffs/vessels	1	101	102
Aquaculture facilities	–	16	16
fixed fishing nets	–	18	18
bulk containers (stowage)	–	35	35
Total	1,536	3,266	4,802

Figure 1. A) Japanese ministry of environment estimates of of debris generated by the 11 March earthquake and tsunami; **B)** tagged (red arrow) mortise and tenon JTMD beam April, 20, 2013 and; **C)** same tagged beam at same location, 20 January 2017.

JTMD collection, processing and analyses revealed a critical lack of information on JTMD composition, diversity and structure needed for risk analyses. Posted videos corroborated the Japanese Ministry of Environment estimates that the bulk of all floating JTMD after the tsunami was wood (Figure 2A). The total amount that was carried away from Japan, however, has not been clear.

The arriving JTMD wood in North America consisted largely of mortise and tenon beams. We marked and tagged all beams occurring on approximately 40 kilometers of remote beach areas in Oregon and Washington (Figure 2B) to permit estimates of JTMD wood residency times, and losses in beach deposits. The tags in combination with photographic records and repeated observations of the debris objects, (Figure 2C) revealed long residences after deposition and relatively low quantities relative to initial projections.

The estimated total wood that accumulated in our study area from 2012 to 2015 consisted of approximately ten beams and 896 kg km^{-1}. Extrapolating these numbers and weights to the 6,000 km southern Alaska to southern Oregon coastline yields only 60,000 beams and 5,375 tonnes of wood. The accumulate wood is, approximately 0.4% of the MoE estimated wood debris. Thus, the North American wood estimate is poor, the MoE estimate is high, most of the floating debris did not cross the North Pacific or, most JTMD has yet to arrive.

Aerial / Vessel JTMD surveys

John Chapman (OSU)

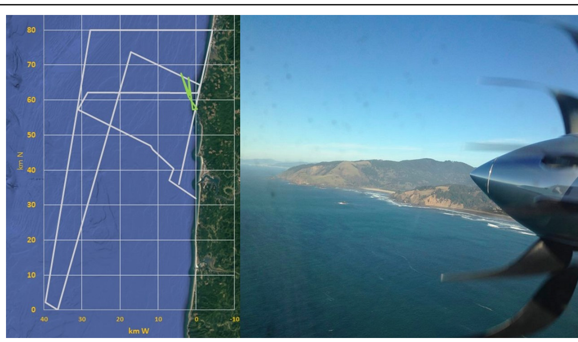


Figure 3. January 30, 2015, air (white) and vessel (green) tracks within the 10 km grid search area between South Beach and Depoe Bay, Oregon completed on January 30 and February 1, 2015 respectively.

We used year 1 funding to test aerial and vessel search methods and estimate at-sea JTMD abundance during winter when maximum JTMD arrivals occur and, presumably when maximum offshore densities of JTMD was occurring. The air and vessel search thus provided a second partial estimate of JTMD abundance.

An unknown fraction of mobile species abandon the JTMD objects (or are otherwise lost) at sea before landfall and then sampling is possible. We performed and aerial search to partialy address this problem on January 30, 2015 (Figure 3, white line). The flight pattern was within a 30 km length by 20 km wide section of ocean between Lincoln City and Waldport, Oregon (Figure 3) where fresh JTMD had landed on beaches within the preceding two weeks. Pilot Bill Frank (Aeromax Avionic) carried us in a twin engine plane for the survey from the Newport, Oregon Airport. The twin engines provided a safety factor that permitted ocean searches beyond the normal 1 mile glide distance from shore. We searched at 300 meters and 125 knots (232 km^{-1}) for 1.5 hours. Our observation angle from 300 m at 60 degrees out of the right side of the plane permitted a search path width of approximately 0.53 km. We marked way points by GPS and summarized the overall flight distance among the turning points. Our search within the 40x80 km area was 173 km^2 (327 km * 0.53 km). Sea birds, crab pot floats and other small floating objects, within the size range of observable JTMD, were readily apparent at the airplane altitude and velocity. JTMD sized objects were not likely to have been overlooked within the search path but JTMD objects were not found.

We tested for JTMD density again on February 1, 2015. Lincoln County Commissioner Terry Thompson and John Chapman searched for JTMD from a 7 m vessel in the Depoe Bay area within the above flight search area (Figure 3, green line). Relevant sized objects were apparent for at least 180 m in all directions from the vessel. The vessel track, measured from waypoints, was 32.3 km. Therefore, assuming and visible all JTMD objects would have been apparent from 180 m in all directions, the 0.36 km by 11.7 km vessel search area was 11.7 km^2. Consistent with the flight observations, all normal JTMD sized objects would have been visible but no JTMD objects were found.

Figure 4. Bagged and loose marine debris processed from the Surfside disposal site, Ocean Park, Washington December 8, 2015. Right top: Chinese fishing float [transoceanic debris that is not JTMD]; bottom right: melted 20 liter buckets colonized by oysters and the barnacle *Megabalanus rosa* [=JTMD]). (Russ Lewis, John Chapman, Marie Barton, with assistance from WDFW Jesse Schultz and others)

We estimate that at least one object would have been found with 95% confidence if three JTMD objects had occurred in our approximately 184 km^2 search area. Thus, higher densities than 3 objects within the search area would not likely have been overlooked. We therefore assumed a density of objects in the search area of no less than 3. Extrapolating from 3 JTMD objects per 184 km^2 in the 40 million km^2 North Pacific would equal only 652,174 total objects when maximum JTMD maximum density close to the North American shore was expected. Thus, again, the North American JTMD estimate is poor, the MoE estimate of JTMD is high, most of the floating debris did not cross the North Pacific or, most JTMD has yet to arrive.

Beach cleanup surveys

John Chapman (OSU)
The third estimate of JTMD volume and mass arriving in North America is from the Russ Lewis and the “Grass Roots Garbage Gang” (GRGG) beach debris removal effort ongoing in Ocean Park, Washington. The GRGG removes all anthropogenic debris from the 12 km northwest end of the Long Beach Peninsula, between Oyster Road and Leadbetter Point. Their cleanups are in parallel with intense beach cleaning activities on the 29 km beach to their south. The Leadbetter Beach is therefore little affected by contamination from other each areas. The GRGG has made approximately 1,299 sweeps (about one every 1.3 days) of their section since June 14, 2012. The debris collected by the GRGG are deposited into a 20 m^3 dumpster that is maintained in a locked, gated 2.5 m high chain-link fenced enclosure. The dumpster is removed when full and Russ Lewis has supplied the timing and “tip load” of each filled dumpster since the beginning of the program. No debris from other sources than the northern 12 km “Leadbetter” section of Long Beach have been deposited in the dumpster. Large debris are photographed. We surveyed the Seaside marine debris dumpster on 27 May, 9 September and 9 December 2015_(Figure 4) to coincide with the maximum accumulated debris loads that are allowed before the "tipping" date (when the full dumpster is emptied and replaced).

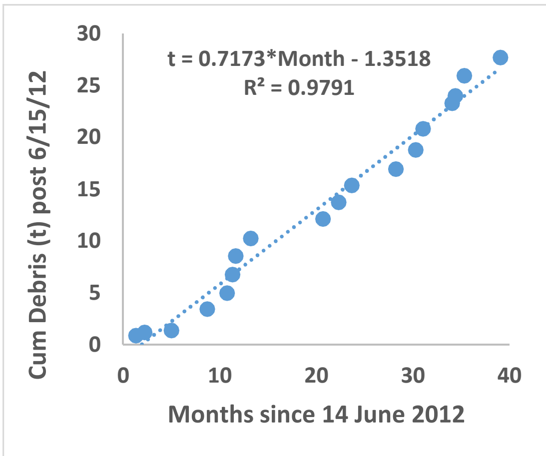


Figure 5. Cumulative debris weight by month on the 12 km north western Long Beach peninsula June 2012 – May 2015.

We separated the JTMD from all other debris from local and long range debris (including items with Korean, Chinese, Russian, and Philippines, Figure 4, upper right) by their unique markings, cultural significance. JTMD are also marked by Japanese kanji characters and are commonly fouled Asian species (Figure 4, lower right). The combined information allows the origins of additional similar objects to be inferred even though such objects may otherwise be lacking in such marks or characteristics. We photographed the debris (i.e., Figure 4) for long-term reference. Less than 25% of the weight and volume of this debris was JTMD.

Total debris accumulation on the 12 km Leadbetter Beach area has occurred a steady 720 km $month^{-1}$ ($r^2 = 0.98$) with less than 3% variation (Figure 5) for the entire period of the program. The total accumulated mass of debris by September 9, 2015 was 39 t. There was no change in debris accumulation that would be expected from an initial large input and then attenuation of JTMD over the study period. There is no sign that more than 25% of total debris over the 27 month study period was JTMD. The total 39 t Leadbetter Beach accumulation extrapolated to the to the 6,000 km Southern Alaska to southern Oregon coastline over the 27 month survey amounts to 19,500 total tons. If 25% of that amount is JTMD, less than 5,000 t of JTMD (excluding boats and floating docks) has made landfall in North America since 2012. Thus, again, the North American wood estimate is poor, the MoE estimate is high, most of the floating debris did not cross the North Pacific or, most JTMD has yet to arrive.

Characterization of JTMD peracaridan crustacean species recovered from JTMD

John Chapman (OSU)

We recovered 17 amphipod species, one tanaidacean species and and four isopod species from JTMD. Four of the amphipod species and two of the isopods species are new records for North America and are indicated in red. Inset species are of unclear morphological distinction within their taxonomic groups. Orange species are unclear taxonomic groups. We partially tested the risk of new invasions from the JTMD transported peracaridan taxa recovered in these samples from the assessed ranges of individual species relative to the zoogeographical diversity of their assessed phylogenetic groups. We assume high risk of new introductions where taxon diversity is geographically variable and, endemism within geographical regions is high, and low risk of new invasions where species endemism is low and taxon diversity is geographically variable. No successful invasions from JTMD crustaceans has been identified. However, it is unknown whether cryptic invasions from JTMD are likely.

Amphipoda	**JTMD**	**Japan**	**Hawaii**	**NEP**	**"Global"**
Allorchestes angusta	X		X	X	
Ampithoe koreana	X	X			
Ampithoe valida	X	X	X	X	X
Ampithoe lacertosa	X		X	X	
Gammaropsis japonicus	**X**				
Jassa marmorata	**X**	**X**	**X**	**X**	
J. carltoni	*x*			*x*	
J. slatteryi	*x*	*x*	*x*	*x*	
J. staudeyi	*x*	*x*	*x*	*x*	
Stenothoe crenualata	X				X
S. dentirama	*x*				
S. gallenis	*x*		*x*		X
Caprella cristibrachium	**X**	X			
Caprella equilibra	X	X		X	X
Caprella mutica	X	X		X	
Caprella penantis	X	X		X	X
Caprella verrucosa	X			X	X
Tanaidacea					
Zeuxo normani	X	X	X	X	X
Isopoda					
Dynoides spinipodus	X	X			
Ianiropsis serricaudis	X			X	X
Ianiropsis derjugini	**X**				
Munna japonica	**X**				

Table 1. North Pacific distributions and biogeographic origins of peracaridan crustaceans arriving in North American on Japanese Tsunami Marine Debris (JTMD) with previous records in upper case X indicating accepted names for this study and lower case *x* indicating uncertain taxonomic status of the sampled populations.

e) Discussion

Three independent surveys, post and beam landings, aerial/vessel ocean searches and long term beach accumulations, indicate that the total JTMD arrivals in the last 5 years are orders of magnitude less than were estimated to have been generated by the March 11, 2011 earthquake and tsumnami. Asian species arrived on the tsunami debris that were not seen previously in North America. The turbulent landfalls of nearly all arriving debris are likely to have permitted escapes of reproductive members of all associated peracaridan crustacean species.

The absence of peracaridan crustaceans on natural JTMD objects (including trees) is in contrast to their numerous and frequent occurrences on artificial, anthropogenic objects. Their greatest abundances and highest densities were on the largest artificial objects. Our data are inconsistent with common prehistoric ocean crossings on natural objects by short-lived coastal marine species. Reproductive populations of all peracaridan species that arrived on North American shores with JTMD undoubtedly escaped into the receiving environments. Evidence that these populations maintained reproductive populations subsequently is lacking. The morphological distinctions of JTMD amphipod species in Japan and North American may be insufficient for direct assessments that are possible by molecular genetics. The geographical mixture of these morphotypes and genotypes suggests that the interactions of these cryptic species allow long-term coexistence on artificial substrates. Of the peracaridan species recovered from JTMD (Table 1), *Ampithoe koreana*, *Caprella cristibrachium* and *Gammaropsis japonica*, *Dynoides spinipodus*, *Ianiropsis derjugini* and *Munna japonica* (recognized from a poor specimen) are new North American records.

f) Challenges

The volumes and weights of all debris arriving on North American shores in all years since the onset of JTMD has been predominantly of North American origins. Access to all JTMD for sampling has therefore only been possible by processing, assessing and excluding larger fractions of non-JTMD items. Nevertheless, JTMD abundances have been sufficient to preclude comprehensive sampling by any effort. Only a minor fraction of all arriving JTMD has been possible to sample. Moreover, most JTMD arrives between March and June, coincident with strong, persistent south winds and inclement weather. JTMD deposition on ocean shores occurs at high tide during the inclement weather associated with south winds in winter. Observers discover most JTMD during low tide access and in fair weather conditions. A majority of JTMD is consequently, discovered days or weeks after landing. Organisms recovered from JTMD are therefore commonly in poor condition and lack large numbers of the associated populations that were lost in the violent surf conditions that occur during on-shore deposition. The overall samples of JTMD are thus unlikely to include the full diversities or abundances of transported Asian species that have arrived. Continued re-analyses of damaged and less than perfectly preserved material improved the accuracy and precision of JTMD species taxonomy. Access to a single open ocean JTMD object (BF-356, Master Register) (Figure 2) allowed a partial assessment of the losses to shore deposition and delayed processing beach accessed JTMD.

g) Achievements

This research established that a diverse assemblage of short lived peracaridan crustaceans capable of self-replication in transit has continued to arrive with JTMD over the years of this study along with long-lived individual members species that have survive in transit on debris since 2011 without replication. The self-replicating JTMD species have potentially longer half-lives of invasion risk for North American communities than the long lived JTMD species.

As second achievement has been to partially assess the total abundances and masses of JTMD that have arrived on North American shores. Far less JTMD has arrived than was suggested by the Japanes MoE to have been carried away from Japan.

h) Literature Cited

5. OUTPUTS

a. Completed and planned publications

Completed:

Calder D. R., H. H.C. Choong, J. T. Carlton, **J. W. Chapman**, J. A. Miller and J. Geller 2014. Hydroids (Cnidaria: Hydrozoa) from Japanese tsunami marine debris washing ashore in the northwestern United States Aquatic Invasions 9(4):425–440 http://dx.doi.org/10.3391/ai.2014.9.4.02

Miller, JA, JT Carlton, **JW Chapman**, JB Geller, Greg Ruiz 2015. The mussel *Mytilus galloprovincialis* on Japanese Tsunami Marine Debris: a potential model species to characterize a novel transport vector, PICES Press, 24(1):24-28. https://www.pices.int/projects/ADRIFT/proj-docs/PicesPress_Jan2016_Mussels%20on%20JTMD.pdf

Planned:

John W. Chapman et al. 2017 [***Asian marine amphipod, isopod, and tanaid crustaceans arriving in North America on terrestrial and marine debris generated by the 2011 Japanese Tsunami***]

John W. Chapman et al. 2017. [***Colonization and Self-Recruitment of a Marine Intertidal Japanese Fly on Rafted Marine Debris Crossing the North Pacific Ocean***]

John W. Chapman et al. 2017. [***Weights and volumes of North American marine debris relative to 11 March 2011 Japanese marine tsunami debris arriving on North American shores between 2012 and 2017***]

Ta N, JA Miller, JW Chapman, T Calvanese, T Miller-Morgan, K Clifford5, JT Carlton ***[The Western Pacific barred knifejaw, Oplegnathus fasciatus (Temminck & Schlegel, 1844) (Pisces: Oplegnathidae) on the Pacific coast of North America]***

b. Poster and oral presentations at scientific conferences or seminars

James Carlton, **John Chapman**, Jonathan Geller, Jessica Miller, Gregory Ruiz, Deborah Carlton, Megan McCuller. Tsunamigenic Megarafting: The Invasion Process Model and the Long-Distance Transoceanic Dispersal of Coastal Marine Organisms by Japanese Tsunami Marine Debris, Ninth International Conference on Marine Bioinvasions in Sydney in January 2016.

Jonathan Geller, Tracy Campbell, James Carlton, **John Chapman**, Philip Heller, Jessica Miller, and Gregory Ruiz. DNA Barcode and Metagenetic Approaches for Monitoring and Surveillance of Marine Invasive Species in North American waters, with Focus on 2011 Japanese Tsunami Marine Debris-Associated Species, Ninth International Conference on Marine Bioinvasions in Sydney in January 2016.

Jessica Miller, James Carlton, **John Chapman**, Jonathan Geller, Gregory Ruiz. The Mussel *Mytilus galloprovincialis* on Japanese Tsunami Marine Debris: A Potential Model Species to Characterize a Novel Transport Vector, Ninth International Conference on Marine Bioinvasions in Sydney in January 2016.

Gregory Ruiz, Jonathan Geller, James Carlton, **John Chapman**, Jessica Miller, Ruth Di Maria, Katrina Lohan, Rebecca Barnard. Japanese Tsunami Marine Debris: Potential Transoceanic Rafting of Bivalve Parasites and Pathogens, Ninth International Conference on Marine Bioinvasions in Sydney in January 2016.

John W. Chapman1, Ralph A. Breitenstein, James T. Carlton Jessica A. Miller, Toshio Furota, Michio Otani, Ichiro Takeuchi, Jessica Porquez, Andrea Burton and Maria Barton 2016. Crustaceans adrift: Multiyear observations of Asian marine amphipods, isopods, and tanaids arriving in North American shores on open ocean drift objects generated by the 2011 Japanese Tsunami, PICES, San Diego, 9 November.

Abstract:

The frequencies of transoceanic colonizations of species on passively drifting objects have been a widely invoked but unobserved explanation of marine species distributions spanning oceans and continents. Diverse reproductive non-native marine species of peracaridan crustaceans (including gammarid and caprellid amphipods, isopods, and tanaids) arrived in western North America commencing in 2012 on drifting objects generated by the Great Japanese Tsunami of 2011. These species survived multi-year open ocean crossings by replacement of multiple generations rather than by individual survival. Given the relatively short life of natural objects (such as wood) on long-distance ocean voyages, successful ocean crossings by short-lived species in modern times may be predominately on artificial, anthropogenic material, leaving natural ocean crossings in prehistoric times in doubt.

James T. Carlton, John W. Chapman, Jonathan B. Geller, Jessica A. Miller, Gregory M. Ruiz, Deborah A. Carlton, Megan A. McCuller, Rebecca Barnard, Nancy Treneman and Brian Steves 2016. Life rafts on the open sea: Successful long-term transoceanic transport of coastal marine organisms by marine debris, PICES, San Diego, 9 November.

Abstract:

A vast number of objects from Aomori, Iwate, Miyagi, and Fukushima Prefectures – ranging from small household items to buoys, vessels, and docks – have been arriving on the shores of North America and the Hawaiian Islands since being sent into the North Pacific Ocean by the tsunami of March 11, 2011. Japanese Tsunami Marine Debris (JTMD) objects with living Japanese species are still arriving as of the date of this abstract submission on July 1, 2016. Examination of the biota associated with more than 650 objects (representing what is likely a small fraction of the amount of debris with living biofouling that has in reality come ashore) has revealed 100s of species of protists, invertebrates and algae, as well as two species of entrapped fish, which have successfully been transported from the Western Pacific to the Central and Eastern Pacific Ocean. Mollusks, crustaceans, bryozoans, hydrozoans, and polychaete worms comprise the majority of rafted invertebrate species. Instances of long distance transoceanic dispersal across the North Pacific are apparently so rare that we have no previous scientific records of living coastal species from Asia landing on the shores of North America or Hawaii by means of rafting. To assess the relative novelty of JTMD we compare this vector to other phenomena, including pre-20th century Japanese shipwrecks, historical and modern shipping (including hull fouling, solid ballast, and ballast water), and the 20th century transoceanic commercial trade in Pacific oysters (*Crassostrea gigas*).

c. Education and outreach

John W. Chapman 2014. Japanese Marine Tsunami Debris (JMTD), Northwest Marine Educators, Seaside, OR 15 March.

John W. Chapman 2015 Can critical densities, diversities or rates of transfer by any mechanism control the arrival and establishment of non-indigenous marine species across a major barrier? Moss Landing Principal Investigators, Moss Landing Marine Laboratory, 20 January.

John W. Chapman 2015. What controls the probability of non-indigenous species establishing from JTMD?, PICES MOE Project Science Team Meeting, Hawaii Prince Hotel Waikiki, Honolulu, Hawaii , March 16-18, 2015.

John W. Chapman 2015. Model System: How Much? How Long? WDFW JTMD Update, Ilwaco, WA, 3 April

John W. Chapman 2016. *HISTORY OF TSUNAMI DEBRIS IN OREGON AND WASHINGTON*: What's washing up now? Beach Comber's Fun Fair, Ocean Shores, WA, 5 March 2016

John W. Chapman 2016. *HISTORY OF TSUNAMI DEBRIS IN OREGON AND WASHINGTON*, Coast Watch, Florence, OR, 5 March

John W. Chapman 2016. *HISTORY OF TSUNAMI DEBRIS IN OREGON AND WASHINGTON*, CoastWatch, Florence Community Center, Florence, OR, 5 March

John W. Chapman 2016. *HISTORY OF TSUNAMI DEBRIS IN OREGON AND WASHINGTON*, CoastWatch, Lincoln City Coast Community College, Lincoln City, OR, 17 May

John W. Chapman 2016. Marine Invasions: The Dark Side of Conservation, Coastal Environmental Management and Resources, Oregon State University, Hatfield Marine Science Center, Newport, OR 4 November.

6. RESEARCH STATUS AND FUTURE STEPS/PLANS

I will continue analyses and reports of past and future Asian peracaridan crustaceans arriving on North American shores with JTMD including the timing diversity and geography of species and rates and quantities of JTMD arrivals in North American shores. A third paper in process includes the morpho-taxonomy of JTMD species relative to their congeneric species.