Kelp raft distribution and associated animal communities in San Juan channel

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Abstract

Nereocystis creates floating debris when broken from the bottom. With currents and wind this flotsam on occasion entangles to form a raft of Nereocystis. Rafting Nereocystis floats throughout the San Juan Islands channels. Here I report the results of surveys and trial studies conducted to study the movement, composition, fauna, density of rafts in channel, and human waste, associated with kelp rafts in San Juan channel. The measurements and collections for the studies utilized snorkeling and SCUBA diving equipment. Transect surveys the R.V centennial on its weekly pelagic ecosystem function cruise. Nereocystis kelp rafts and other flotsam is a relatively unstudied subject. My aims in this study included determining the relationships in the pelagic ecosystem with which Nereocystis rafts overlap; whether forage fish aggregate or use the raft as a feeding area; and whether predators attract to rafts. Nereocystis rafts are a refuge for benthic organisms in a pelagic environment.

Intro

The floating islands of kelp in San Juan channel create diverse communities and structures that allow attachment for benthic invertebrates which may use the rafts as refuge. The movement of kelp rafts is affected by oceanic forces such as currents and winds. This may help animals such as *Pandalus eous*, *Melibe leonine*, *Oregonia gracilis* and many other species to disperse around the San Juan's and the Salish Sea. This refuge allows invertebrate fauna relief from predation and currents. The research I conducted examined the abundance and movement of

Nereocystis rafts in San Juan channel, the dynamics related to kelp strand association and aggregation and faunal diversity associated with kelp rafts and their distribution.

Floating detached kelp rafts serve as an important means to transfer structural habitat normally associated with benthic into the pelagic environment. These rafts may also serve as important means to transport and disperse associated biota across relatively large distances.In the Southern Pacific Ocean, biogeographic studies have shown that *Macrocystis pyrifera* and *Durvillaea antarctica* have the potential for long distance invertebrate dispersal (Smith 2002). In 2009 and 2012 *Durvillaea antarctica* was recovered on a beach in New Zealand. with genetic analysis from amphipods still inhabiting the raft, it was estimated the raft had drifted from the Snares Islands 390 km or 600 km from the Aukland Islands (Fraser et al, 2010). By genetic or distributional evidence a total of 1205 species have been confirmed to be common rafting organisms from all major oceans (Thiel, Gutow 2005).

Kelp rafts may also alter feeding strategies of important pelagic predators and facilitate access to otherwise inaccessible resources. In the Bay of Fundy (Canada), Balearic Shearwaters have displayed an alternative feeding strategy for floating seaweeds which involves the capture of fish under the raft. The rafts attract phalaropes, gulls and terns (Vandendriesschs ,et al 2007). This is in the pursuit of easily captured prey. In North Eastern Atlantic Razorbills, Fulmars, Sea ducks, and Guillemots associated with floating seaweed were found to be actively pursuit-plunging or actively searching floating seaweeds (Vandendriesschs et al, 2007).

Kelp flotsam is an important resource for feeding predators and a distribution device for benthic animals to distant shores. In the San Juan Islands this could be an important mechanism

increasing the diversity of benthic animals throughout the Salish Sea. The movement of kelp rafts in the San Juans and Salish Sea may also be involved in the dispersal of human waste, and could be a potential disperser of invasive species. My aims are to explore where these rafts move and to identify and quantify what marine fauna inhabit the kelp blades. This information can increase understanding of the mechanisms behind distribution of species through the Salish Sea and the global ocean.

Methods

Using the resources at University of Washington's Friday harbor laboratories located on San Juan Island in the San Juan archipelago from the dates of September 20th 2012 to November 20th 2012, I conducted several pelagic surveys of Nereocystis flotsam called kelp rafts. The surveys in San Juan channel where to look at fish aggregation, raft movement, fauna diversity/ biomass and kelp raft distribution.

Fish aggregation observations by Snorkel

To assess fish aggregation behavior under *Nereocystis* rafts, a team of three divers using snorkel gear observed and documented fish numbers under 8 kelp rafts in Friday Harbor. Due to cold water temperatures, dives were restricted to two hours per day for the safety of participants. On October 16, 2012 kelp rafts were chosen based on opportunistic visual encounter from the Auklet on, a member of the Friday Harbor Labs fleet of research vessels. We approached an area of Friday Harbor with multiple kelp rafts; three divers entered the water in the vicinity of the kelp rafts while the tender kept visual and verbal contact with the dive team and displayed the appropriate dive flag to alert nearby mariners. The three divers in the water swam to a

single kelp raft, surrounding it to provide observations on all sides of the raft. In this manner we were able to observe fish that fled the approaching swimmers. One of the divers verbally signaled intent to descend; swimming below the surface, the descending diver made counts of all visible fish under the kelp raft. Kelp raft size and composition were documented, as well as presence and amount of human wasted such as plastic or Styrofoam. Counts were immediately relayed to the tender of the Auklet; this protocol was repeated for all 8 kelp rafts. 21 rafts where surveyed for the fall this was divided with the number of rafts with fish.

Tracking kelp raft through mark recapture methods

I attempted to track kelp raft movement and size change in San Juan channel. I constructed and deployed 6 tracking buoys made of 2 ft long, 1”X1” wood, a concrete weight to prevent capsizing, and two recycled net floats to achieve buoyancy. Each tracking buoy carried a numbered identification Kelp rafts were located opportunistically by visual encounter aboard the Bufflehead. With a crew of two tenders and one snorkel diver, the Bufflehead was maneuvered within 30 feet of a kelp raft. The snorkel diver entered the water with a 100-foot tape measure and recorded the size of the kelp ball in three dimensions including depth. Depths greater than 15 feet were visually estimated, because of safety restrictions placed on free-diving snorkelers. The composition of the kelp raft was recorded; then a tracking buoy was placed in the center of the raft and tied to a kelp stipe with nylon line. Time and GPS location of the raft were recorded when the kelp raft was deployed. A total of 6 kelp rafts were marked in

this manner. The following day, visual observations with binoculars were conducted aboard a 40 foot motor vessel within northern San Juan channel, and again the second day after releasing the tracking buoys, this time aboard the Auklet. The location of the single tracking buoy I was able to recover after 2 days was marked using GPS coordinates.

Diving surveys and sampling

I made SCUBA and snorkel-based sampling efforts on kelp rafts to collect raft-associated fauna. Aboard the Coot, kelp rafts were opportunistically located by visual observation. For SCUBA based sampling efforts, two divers entered the water, and signaled an "OK" to the tender, who passed to one diver a 202µm plankton net. The divers compacted the net to prevent unwanted material from entering prior to sampling. Both divers descended to the base of a single *Nereocystis*. Depth was recorded. The plankton net was opened under the blades of the kelp, then both divers ascended holding onto the net and assisting kelp blades into the net, collecting all of the blades from a single kelp stipe. The mouth of the net was held above the surface of the water to prevent loss of sample and to prevent water and animals from washing in at the surface. The head of the kelp was removed with a sharp bladed knife, and the entire net was handed to the boat tender. The net was rinsed before loading onto the deck of the Coot, then the blades were rinsed and placed back in the water, reserving all animals associated with the stipe. The contents of the net were placed in a 1L bottle labeled with the kelp raft and sample number, and the depth of the plankton tow. Two samples were taken from each raft, one from the center of the raft and one from the outer edge. The kelp raft was measured in three dimensions including depth; any garbage found associated with the kelp raft was removed. GPS

location of the raft was recorded. Independent snorkel-based sampling efforts were made at the Friday Harbor Laboratories pier with dock support. Methods were the same with the exception that in-water sampling was made by a single swimmer and depths were less than 15 feet. Formalin was added to all samples in as short time period as possible

In lab

The samples collected from the rafts in one liter bottles were transported to the lab where their contents were strained using a 150µm filter. The samples were then placed in labeled 100 ml containers with a weak formalin solution. Each container contained all animals and material from a single kelp stipe. The animals from these samples were identified and each species was counted and each species group was weighed. If the animals where to light to be weighed only the numbers were taken.

Visual transect surveys of kelp raft abundance and distribution in San Juan channel

Kelp rafts in the San Juan channel were counted from the RV Centennial along the pelagic ecosystem function transect. Visual surveys were conducted two hundred yards from either side of the vessel using binoculars. Kelp rafts were assigned to three size classes: small, medium, and large. Small rafts were 1-4 stipes, medium were 5 stipes to rafts 15 feet in diameter, by visual estimate. Large rafts were larger than 15 feet in diameter, again by visual estimate. Four surveys were made on two different days through the 6 transect zones. These zones were predetermined by the pelagic ecosystem function course for their position in the San Juan channel. The transect started ½ a mile to the west of Yellow Island the transect ran

south for 8.6 miles to end off of salmon bank buoy south of San Juan island. Zone changes were announced by boat skipper when passed on GPS.

Results

Fish aggregation

In Friday Harbor, I did 8 exploratory surveys on *Nereocystis* rafts for fish aggregation. Fish where found in the vicinity of 4 kelp rafts in the initial surveys (table 1). In the 21 kelp rafts surveyed fish where found under and in the vicinity of 20%.

Kelp raft movement

documented the movements and changes in size of kelp rafts in San Juan channel. On November 1, 2012, six tracking buoys each with identification were placed on measured *Nereocystis* rafts and marked with a GPS location (table 2). We recorded fauna associated with the kelp, as well as human garbage which often aggregates in tangled floating kelp masses. Kelp raft FHL 3 was recovered on November 5 on the beach at Friday Harbor labs; the raft had moved 2.3 miles from Yellow Island. FHL3 was the only kelp raft that we recovered.

Fauna diversity, biomass and density

Fauna diversity, biomass and kelp raft measurements were sampled on 9 *Nereocystis* rafts in San Juan channel and Friday harbor on November 15, 2012 and November 16, 2012. From the 9 rafts, 26 samples were taken the animals we collected were identified, counted and weighed. By count and weight *Pandalus eous* was most prevalent species, followed by amphipods of unsorted species (figure 1). The other species identified were Pandalus danae, Isopoda,

Oregonia gracilis, Caprillidae, Megalops and Melibe leonine. The biomass of the animals associated with kelp rafts was calculated (figure 2) and compared for small, medium, and large rafts. Large kelp rafts showed greater diversity and biomass than smaller, but density of fauna was much higher in the small rafts (figure 3).

Kelp raft distribution in San Juan channel

Kelp raft distribution was surveyed along the pelagic ecosystem transect four times over a two day period. Observations made at different time points were averaged for each zone; zone 3 and 4 had the most kelp by count (figure 5). The number and sizes (figure 6) showed that small rafts where the most prevalent followed by medium then large.

Biomass of fauna on rafts in San Juan channel

To find the average biomass of animals associated with *Nereocystis* rafts in San Juan channel. I used the average number of kelp rafts counted from the transect and the averaged biomass of fauna for each size of kelp. The biomass of fauna for the rafts was, small 12 lbs, medium 2.8 lbs and large 2.5lbs for a total of 17.3 lbs. of animals (figure 7)

Discussion

Kelp flotsam in the Pacific Northwest is a relatively unstudied subject. Kelp flotsam is a piece of a benthic community that is released into the pelagic ecosystem. In the San Juan channel pelagic ecosystem surveys on *Nereocystis* rafts were conducted utilizing observations from the RV Centennial and SCUBA/snorkel based surveys and collections on Nereocystis flotsam located

in San Juan channel. The aims of these studies were to investigate fish aggregation beneath Nereocystis rafts; track kelp raft movement and changes; quantify biomass and diversity of macro fauna on Nereocystis rafts; and characterize Nereocystis raft distribution in San Juan channel.

It was concluded that fish aggregation beneath rafts does not occur in the San Juan channel as it does offshore, although the rafts do seem to be used by fish. The schools of fish observed near kelp rafts may be using the raft briefly as refuge, or feeding on invertebrates that are persistently associated with kelp formations. Future research on kelp rafts would benefit from the use of a purse seine in order to capture an entire kelp raft 10 ft out and past the bottom of the kelp blades. This would allow for all fish in the vicinity of the raft to be captured for counting, identification, or other sampling.

Attempts at kelp raft tracking were intended to assess how far the rafts moved, how fast and if they changed in size over that time period. Using tracking buoys, I hoped to recover and re-measure the rafts I had marked. Despite multiple surveys throughout San Juan channel only FHL3 was located when it washed up on the beach at Friday harbor labs. In the future a live feed waterproof GPS unit would greatly improve likelihood of recovering marked rafts. This would allow a complete record of kelp movement during the study period and facilitate interception of the raft make observations, measurements and to retrieve and recharge the GPS unit to be deployed again.

Results from direct sampling of raft-associated fauna indicate that there is a correlation between kelp raft size and faunal diversity. We also observed a negative correlation between

kelp raft size and the density of associated invertebrates, but because of the small number of replicates, we cannot make conclusions about the relationship between density and kelp raft size. Kelp rafts greater than 15 feet in diameter contained more biomass but also more diversity than smaller kelp rafts. This could be because of greater surface area, which increases available habitat and creates more niches for animals, especially invertebrates, to take hold. Of the species present, the most prevalent were *Pandalus eous* juveniles, a commercially fished species; and amphipods of unknown species. These along with the other fauna seem to use the kelp raft as a benthic replacement refuge. For these benthic living and pelagic feeding shrimp it would allow a protected space in the pelagic ecosystem to feed and hide, without needing to return to the bottom.

Kelp rafts are created by currents, wind and waves. These forces are what move them through the channels of the San Juan's and the Salish Sea. With the 4 transects that I conducted on the R.V Centennial showed rafts to most likely be located in zone 3 and 4. This is in a convergent zone of currents from Upright channel and San Juan channel. There are kelp beds located in that area due to its strong currents, which wash in a steady supply of nutrients. From which beds these *Nereocystis* flotsam come and how far it travels is unknown, but the fluctuation can be correlated with strong weather and extra high tides. I would like to conduct more transects through the San Juan's to compare zones of current convergence and find how much flotsam there is in these areas and the rafts correlation with weather.

Acknowledgements

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Tables and Figures

Table 1

raft	fish fauna	demension	garbage
1	1 stickle	5	bag
2	0	5	plastic
3	2 herring	7	foam, plastic
4	0	6	wrapper
5	300 herr E	10	tennis ball
6	0	6	cup
7	0	8	bag
8	1	20	back pack

Table 1: observations were made, no measurements

Table 2

Raft	Dimentions l/w/d ft	Fauna	Garbage	Composition	Lat/Long Nov 1	Marker	recovered Nov 5 Lat/long
1	28/14/17	2 hooded Nudibranks	none	eelgrass, Arbutus, Nereocystis, fucus, red algea, leaves, pine neadle	N 48' 32.889 W 123'00.365	FHL10	
2	33/12/30	2 HN, Isopod	plastic foam	bird feathers, Nereocystis, eelgrass	N 48' 32.904 W 123'00.333	FHL4	
3	24/15/15 blades-30	Shrimp	tennis ball, foam, net	wood, nereoosystis, eelgrass	N 48' 32.902 W 123'00.336	FHL8	
4	13/6/17	none	none	some eelgrass, green algea, Nereocystis, stipes entaingled	N 48' 33.886 W 123'01523	FHL7	
5	12/16/8.	none	none	Nereocystis, eelgrass	N 48' 35.104 W 123'01.787	FHL9	
6	26/14/13	none	foam	Nereocystis, eelgrass, cedar, feathers	N 48' 35.163 W 123'01.853	FHL3	N 48' 32.775 W 123'00.608

Table 2: Kelp raft tracking and measurements

Table 3

Kelk Raft #	Date	size	Length	width_me	depth_me	Depth	Area	depth of tow	depth of water	Make up	Animals	plastic	Lat Long
1	11/15/2012	M	6	2.5	4.878049	16	73.17073171	15ft	120ft	Nereocystus, eelgrass, fucus	3 hooded noodebranks, shrimp		N 48' 32.756' W 123'00.418
2	11/15/2012	M	4	3.02	2.439024	8	29.46341463	12ft	20ft	Nereo, green Algea, eelgrass, bird f	1 petropod, shrimp		N 48' 32.738' W 123' 00.691
3	11/15/2012	M	5	2	3.353659	11	33.53658537	11ft	12ft	Nereo, wood, eelgrass	shrimp		N 48' 32.729' W 123'00.739
4	11/16/2012	L	9	3.2	4.878049	16	140.4878049	11ft	50ft	nereo, eelgrass, fucus, bird feather	300 herrin	2 bottle, line, foam, plastic	N 48' 32.730 W 123'00.890
5	11/16/2012	L	11	3.7	6.097561	20	248.1707317	8ft	22ft	Nereo, eelgrass, driftwood, fucus, l	shrimp	wrapper, rope, foam, lighte	N 48' 32.734 W 123'00.700
6	11/16/2012	L	14	5	4.573171	15	320.1219512	12ft	40ft	Nereo, eelgrass, driftwood	shrimp	snorkel	N48' 32.750 W 123'00.900
7	11/16/2012	S	3	1.2	1.829268	6	6.585365854	6ft	20ft	nereo	shrimp		N48' 32.740 W 123'01.000

Table 3: Kelp raft measurements and observations for collections

Figure 1

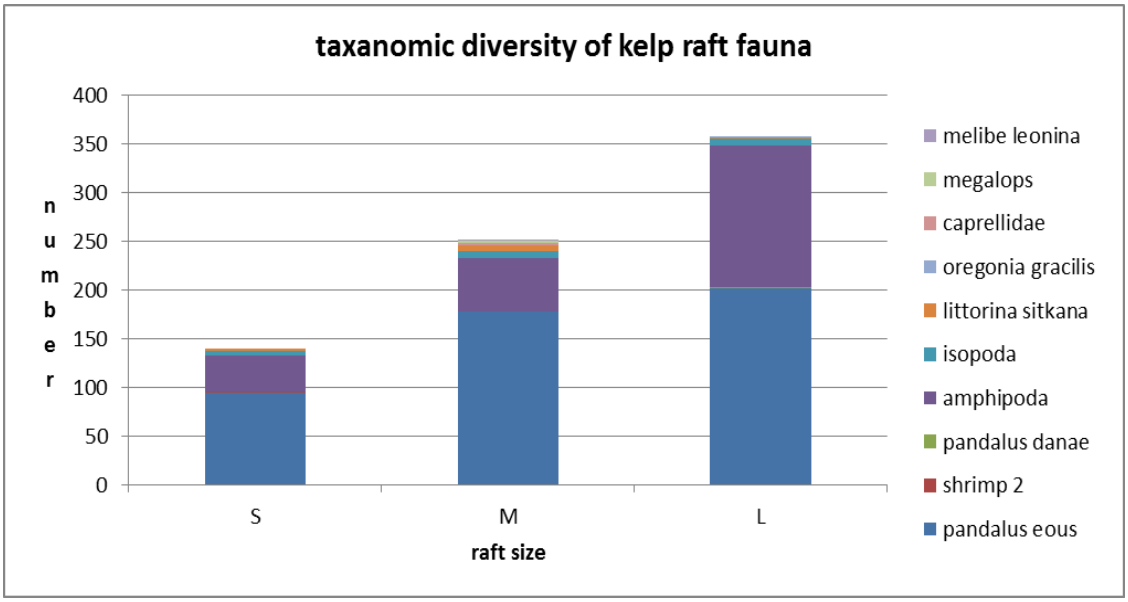

Figure 3: shows diversity in small medium and large rafts

Figure 2

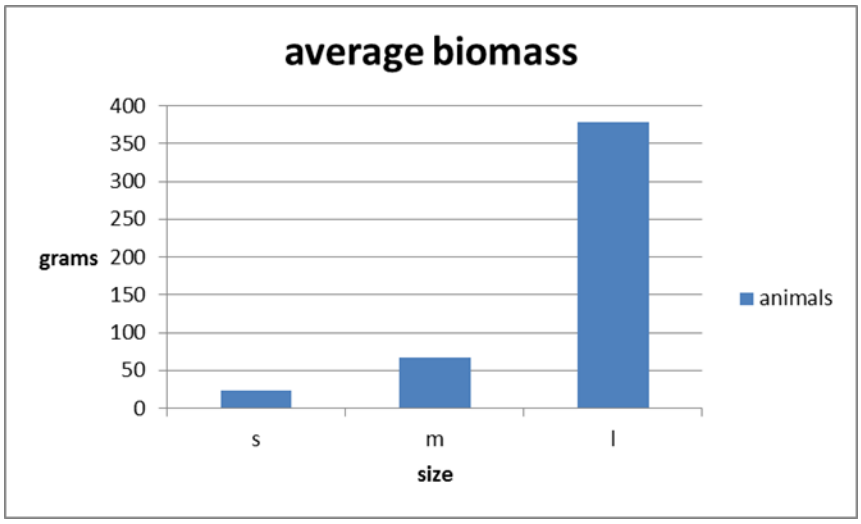

Figure 2: Average biomass of fauna on small, medium and large kelp rafts

Figure 3

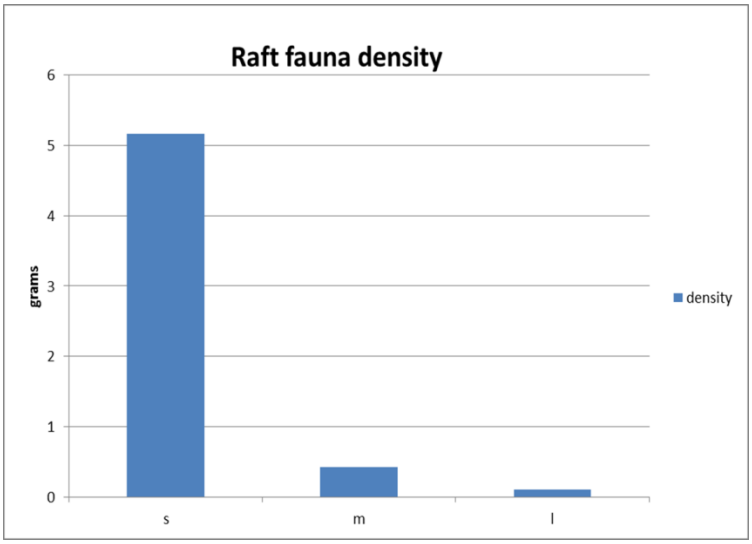

Figure 3 shows that the density in a small raft is much greater then a large

Figure 4

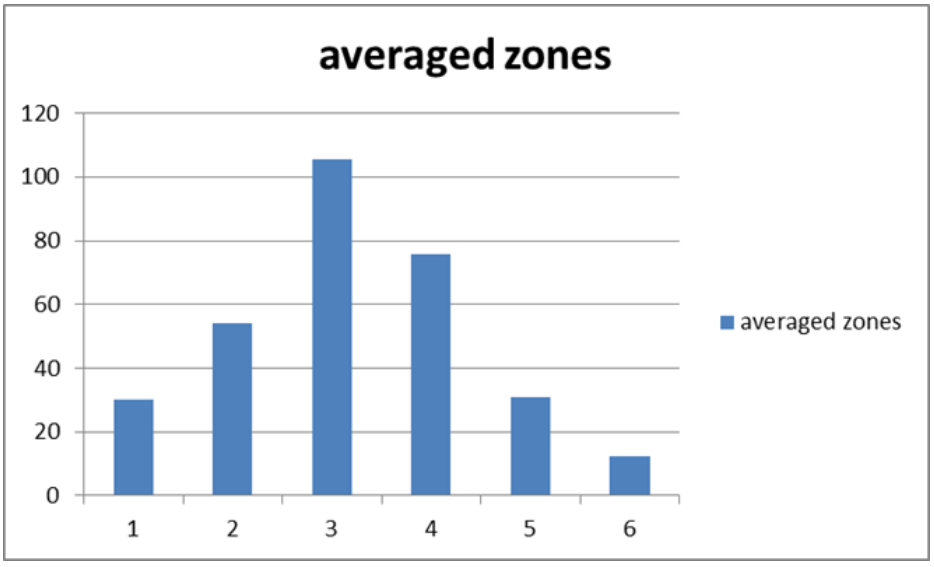

Figure 3: The averaged kelp rafts in zones 1-6

Figure 5

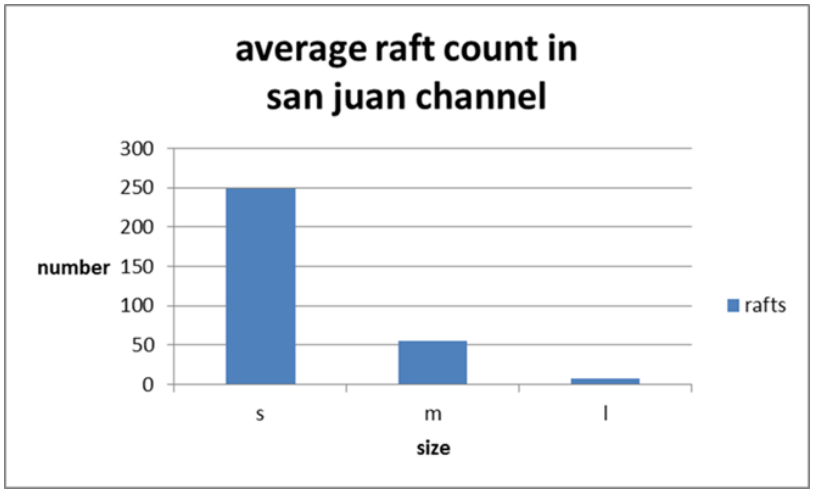

Figure 5: The average count of small, medium and large kelp rafts in San Juan channel

Figure 6

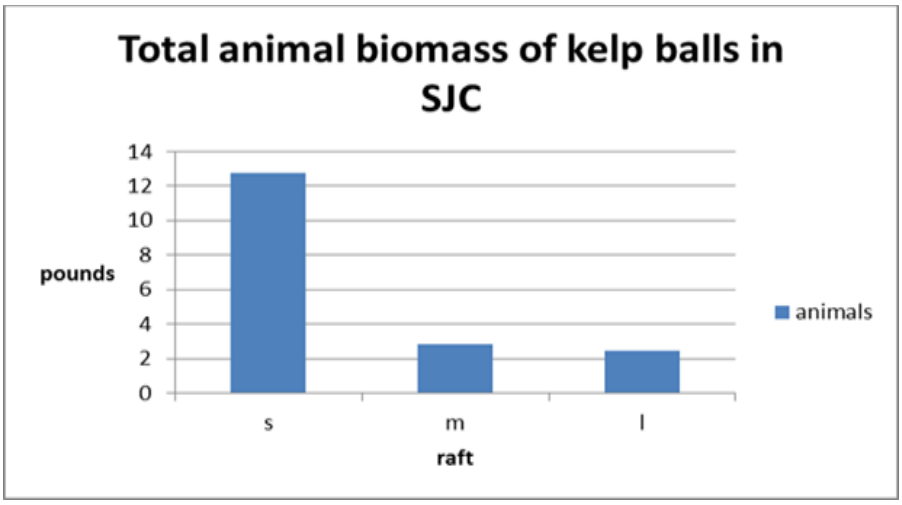

Figure 7: Total of all fauna biomass on kelp rafts in San Juan channel