A kayak-based survey protocol for Bull Kelp in Puget Sound

Prepared for the Northwest Straits Commission

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Background:

Large brown algae in the order Laminariales, commonly known as ‘kelp,’ provide habitat to a variety of species in Puget Sound, and are considered critical habitat warranting protection via Critical Area Ordinances, Shoreline Master Plan updates, and NOAA Fisheries provisions for endangered rockfish. Kelp, like eelgrass, also contributes other valuable ecosystem services - food for many creatures, protection from coastal wave energy, and more.

Conspicuous declines in the abundance of bull kelp (*Nereocystis luetkeana*), the prominent canopy-forming species in Puget Sound, have been observed in many areas. The causes of decline are likely due to a combination of factors. An annual inventory conducted since 1989, by the Department of Natural Resources (DNR) through aerial and dive surveys, has focused on the floating kelps - including *Macrocystis integrifolia* - of the outer coast and Strait of Juan de Fuca. There, kelp abundance has increased.

Intensive monitoring is ongoing at the mouth of the Elwha River, in concert with long-term restoration, where there have been dramatic changes in kelp distribution. Little information is available on the status of bull kelp populations in northern Puget Sound, or on changes to these populations over time.

This survey protocol has been prepared as a reliable and relatively simple tool for Northwest Straits Marine Resources Committee (MRC) volunteers and other citizen-scientists monitoring bull kelp toward its protection and recovery.

Our question:

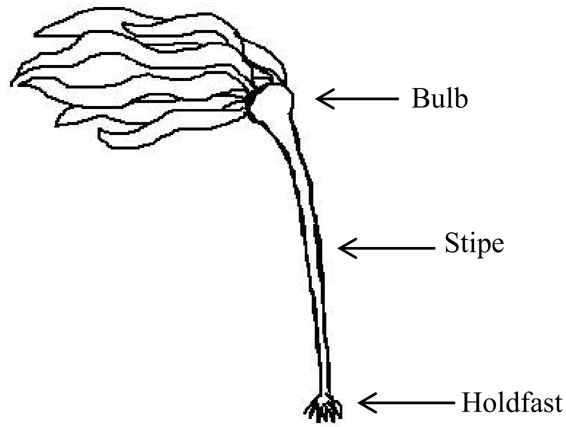
Can current distributions and patterns of change in bull kelp populations be accurately and repeatedly surveyed by citizen science volunteers, from the surface?

Cover photo: Bull kelp bed in San Juan County; Emily Bishop

Northwest Straits Kayak-based Survey Protocol for Floating Bull Kelp Beds

A field guide to track presence of bull kelp, *Nereocystis luetkeana,* in Puget Sound

Materials:
- Kayak
- Aerial photo, map, or chart of area
- Handheld GPS unit
- Datasheets (attached)
- Weighted line (marked in feet)
- Thermometer (marked in °C)
- Camera
- *Plankton net
- *Bucket/graduated cylinder
- *Labeled Falcon tube with approx.
- *10mL of ethanol



*Only used if comparing zooplankton communities in and outside of kelp beds

Methods:

A. Identifying kelp beds
Bull kelp beds will be defined as a cluster of *Nereocystis* plants greater than 5 meters (16.5ft) across. Individual kelp bulbs greater than 8m (26ft, about 1.5x the length of a typical sea kayak) apart will be considered part of a separate bed (see Figure 1).

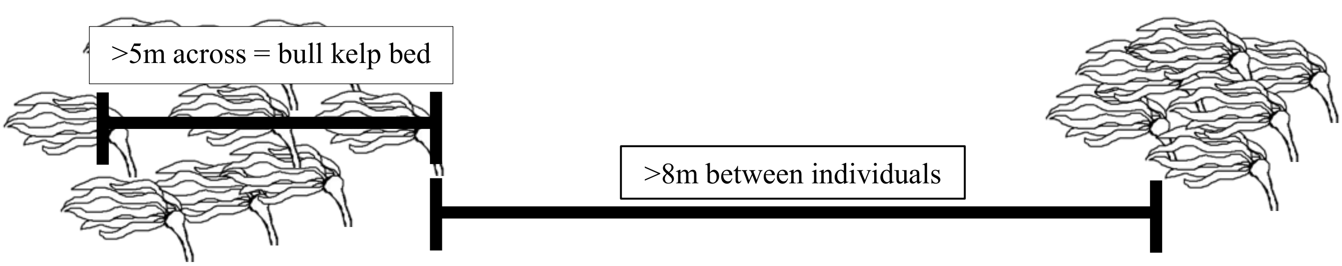


Figure 1. Measurements for identifying distinct kelp beds

General guidelines for selecting areas to map: choose a known location along a stretch of shoreline that will be easily identifiable in future years. During initial testing of protocol, it is advised that beds less than 1000m (~0.5mi) in length be selected[i].

Consider a pre-survey scouting trip to your selected kelp bed before attempting a full survey.

B. Choosing appropriate time to perform surveys

Surveys will be conducted:

- at low tide, when the water level is less than 0.0ft[ii] Mean Lower Low Water (MLLW)[iii].
    - Use a tide chart (available online from sources such as www.tidesandcurrents.noaa.gov, www.tides.mobilegeographics.com, or on smart phone apps such as "Ayetides" or "MultiTide") to determine the exact length of time during which the water will be below 0.0ft MLLW during late July through mid-September[iv] each year. Base number of surveys on your organizations goals and objectives.
- within one week of the previous year's survey date, for comparison of data between years.

C. Pre-survey preparation

1. Be familiar with GPS operation[v].
2. Designate a trip leader who will be responsible for the following:
    - Check GPS battery level.
    - Set the GPS to record its position every 10 seconds, about every 2m.
    - Assure that safe weather and maritime conditions are projected. Confirm conditions from the beach for your safety. See "current speed" below.
    - Bring a simple pool thermometer, a weighted line, and a GPS to survey.

<u>Current speed</u>

Survey days should be selected with current speed in mind, both for the safety of boaters and to prevent excessive pull on bull kelp during surveys. **Your personal safety is the priority.** Record current speed on datasheet using a source such as www.tides.mobilegeographics.com.

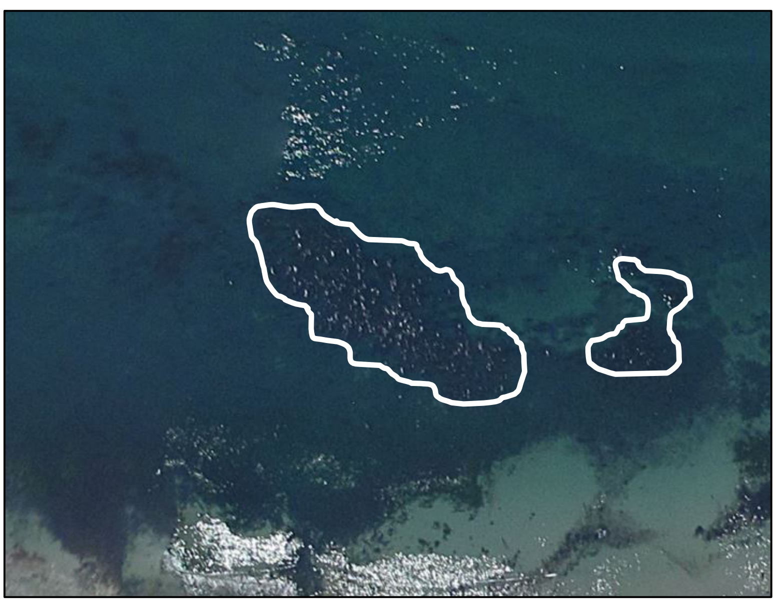


Figure 2. Aerial photo of two bull kelp beds on the west side of Whidbey Island; Gregg Ridder

D. Conducting the survey

3. On the beach, turn on the GPS unit and situate it pointing towards the sky while it warms up.
4. Fill out the Pre-Survey section of the Data Sheet.
5. **Name or number each bed** you wish to survey on the data sheets. Each bed should have its own "on the water" data sheet. Refer to previous years data sheets if beds were previously surveyed.
6. Bring the thermometer, weighted line, GPS, and paddle out to the kelp bed.
7. **Take the surface temperature** of the kelp bed with the thermometer, within the top 0.5m (1.6ft) of water.

<u>Depth</u>

8. On the perimeter of the bed closest to shore, lower a weighted line into the water until there is slack. Pull back the line slightly and then lower again for a precise measurement. Pull back the entire line and **measure the amount that was underwater.**
9. Record a GPS point where the depth was measured and the time of the measurement.
10. Repeat Step 11 once more on the perimeter of the bed opposite from shore.
11. Record GPS point where the second depth measurement was taken and the time of the measurement.

<u>Perimeter</u>

12. **Take a waypoint, start recording a track** and paddle around the perimeter of the bed. Stay within 1 m (3ft) of the outermost plant.
13. Once the perimeter is completed, **stop recording tracks and take the final waypoint**.

<u>Photos</u>

14. Take **four pictures**[vi] of the kelp bed (Appendix A). Take one on the water side facing shore (Towards beach: ToBe), one on the shoreward side facing the water (Towards water: ToWa), one with the beach on the left (Beach on left: BeL), and one on the opposite side with the beach on the right (Beach on right: BeR)[vii]. The angle of the photos should try to capture as much of the bed as possible, while still including the horizon or a land feature. Keep track of which picture corresponds to which photo point by taking the picture, then taking a picture of the data sheet with the box for that photo point checked off. Repeat for a total of four photo points. Take additional pictures of volunteers in action.

<u>Observations:</u>

15. List any observations to describe the kelp community or factors that may be impacting it[viii]. Record visible damage to plants, kelp crabs eating things, birds, fish, mammals present. Does it look healthy? Any obvious bulbs left over from previous season? Do they look like they're persisting – huge, blades ratty, epiphytes present? Is it a thin bed, thick bed? If there is no floating kelp visible at the site, record what you find instead. Is it barren? Is there understory kelp? Are there any human related influences on the bed? Also consider taking photos of your observations. Record photo label in the observations section.

REPEAT FOR EACH KELP BED

E. Post survey process back on shore

Fill out Post-Survey section of the data sheet when back on shore. The trip leader should fill out the post-survey checklist. The trip leader should confirm that all data sheets are completely filled out and that photo points were recorded. Upload photos and save photo points with file names that include the bed name, date, and photo point name (i.e "NorthBeach5.24.16ToBe.JPG").

Each MRC should file and store datasheets and photos for floating kelp beds within their county. GIS mapping and uploading of data to SoundIQ will be coordinated by the Northwest Straits Commission.

<u>Optional</u> <u>Zooplankton Sampling Methods*</u>

This component is included for those who aim to document zooplankton-kelp associations. Zooplankton monitoring is a regional priority as identified by the Puget Sound Ecosystem Monitoring Program, Salish Sea Survival Project, and others. Kelp surveyors can participate in the growing effort to track community assemblages of zooplankton in Puget Sound.

* Priority taxa for zooplankton-kelp surveys should be specified ahead of time by the MRC. A comprehensive zooplankton survey protocol and zooplankton ID card are available (see appendices).

Plankton nets can be constructed with simple materials to reduce expense. Cut 2 inch PVC pipe into 25cm segments, and cut 200µm Nitex bolting cloth into 3.5 inch diameter circles. Pinch the Nitex circle between two segments of PVC pipe, and secure with a coupler (Figure 4).

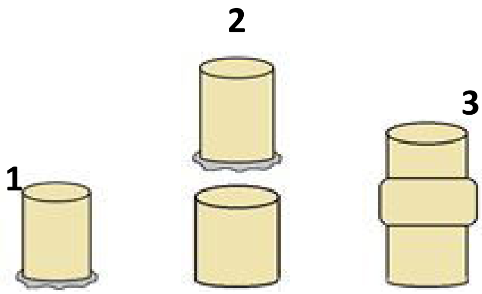


Figure 4. Plankton net construction.

Before collecting a sample, rinse out a small bucket or graduated cylinder three times with water at the collection site. Collect 500mL of surface water (within the top 0.5m or 1.6ft) from the center of the kelp bed (pre-measure and mark a fill line, or use a graduated cylinder) and pour through the plankton net (Figure 5). When finished, remove the Nitex circle containing the sample, making sure to only touch the edges. Store the sample in a labeled Falcon tube pre-filled with ethanol. Repeat the process 15 meters away from the offshore edge of the bed.

Identify taxa under a microscope, or refrigerate samples for later comparison of plankton communities inside and outside of surveyed kelp beds.

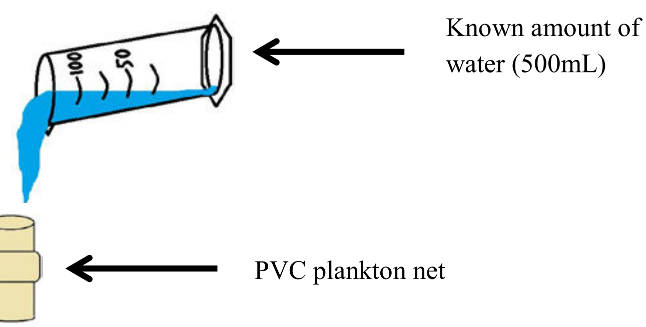


Figure 5. Zooplankton sample collection

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Glossary of Acronyms

GPS: Global Positioning System
MLLW: Mean Lower Low Water
MRC: Marine Resources Committee
NOAA: National Oceanic and Atmospheric Administration
PVC: Polyvinyl Chloride

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Appendices

A. Example map of photo points

B. Bull kelp survey datasheet

C. Sample datasheet for reference

D. Zooplankton sampling protocol – Julie Keister

E. Zooplankton ID card – Washington Sea Grant

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[i] Alternatively, one large bed could be surveyed using multiple GPS units and multiple surveyors paddling around the bed simultaneously.

[ii] One goal for summer 2016 surveys is to investigate the variation in size of bull kelp bed perimeters at different tidal heights. Consider conducting the survey at a -1.0’, +3.0’, +5’ft tide and comparing the results. Similarly, consider having multiple surveyors make a GPS perimeter track at the same tide height to compare the variation between surveyors.

[iii] Some beds may be exposed on the beach during a 0.0ft tide. In this case, kayak around as much of the bed as possible and then make a note on the data sheet that the shoreward perimeter is too shallow to paddle around.

[iv] Likely once per month. One goal is to determine how much perimeters change between months.

[v] If feasible, conduct preliminary surveys with multiple GPS units to compare variation in perimeters using different units and multiple surveyors.

[vi] Photos will not be used to calculate the density of beds surveyed. The goal is to have photo documentation of changes in the bed over the course of the season, and between years. Surveyors should decide during their first survey, or possibly during a pre-survey scouting trip, specific locations for photo points on each side of the bed that will be easiest to replicate (picking a nearby landmark for the background is a great way to ensure the pictures are replicable).

[vii] When taking pictures, it is essential that surveyors remember which pictures correspond to which photo points. This may not always be an easy thing when uploading pictures after a long day in the field! Variations on this method may be useful, such as if the data sheet and the camera are being held by surveyors in different kayaks. For example:

Scenario: Kelly Kelp has the camera but Phil Plankton has the data sheet

-Kelly takes photopoint ToBe, and then the next picture she takes is one of her paddle
-Phil makes a note on the data sheet that the sequence is "ToBe, paddle"
-Kelly then takes photo point ToWa and then a picture of a heron
-Phil adds to the note on the data sheet: "ToBe, paddle, ToWa, heron"
-etc

This way, when Kelly -or another surveyor- uploads the photos and goes to rename them, there will be no confusion about what each photo is depicting.

[viii] Surveyors should not feel limited to the suggestions provided here. Any qualitative notes may be useful in future analyses.

Appendix A. Photo point map

Bull Kelp Survey Data Sheet (on shore)

Pre-Survey Section (on the beach)

Names of surveyors: ____

Location: ____

Date: _______________ Weather conditions (circle one)

Clear Clouds Heavy rain Light rain Fog/mist

Tide height (ft): Start________ Tide station:____________________________

Current (knots): ________________Station/source: ___________________________________

Name of GPS unit or phone app __________________________Accuracy of GPS: +/-_______ft

- ☐ Proceed to page 2 to conduct survey. Following your survey, fill out Post-Survey section below.

Post-Survey Section (back on the beach after the survey)

Provide a sketch of the area surveyed, including approx. location of kelp bed boundary line, temperature, depth measurements and locations of photo points.

Post-survey checklist:

- ☐ Kelp bed perimeter track is saved in one or more GPS units
- ☐ GPS units are collected for storage until next survey
- ☐ Data sheets are completely filled out and legible.
- ☐ Photo points have been taken (and are later uploaded with properly labeled names)

Bull Kelp Survey Data Sheet (on the water)

Kelp Bed number or Name ______________________

Start time (time of temperature measurement):____________

Water Temp. (°C): __________

Depth (ft):

Edge closest to shore: ________ft, GPS Point name: _____________ Time: ____________

Edge farthest to shore: ________ ft, GPS Point name: _____________Time: ____________

Perimeter:

GPS point name at beginning of paddle around bed: ______________

GPS perimeter track name: ______________

GPS point name at end of paddle around bed: ______________

Photo points: (take first photo, then immediately take a photo of this data sheet with the corresponding box checked off)

☐ **ToBe** ☐ **ToWa** ☐ **BeL** ☐ **BeR** ☐ **Volunteer photos**

Observations (consider density, animals present, overall health of blades, presence of understory kelp, human impacts, etc.)**:**____

____

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____

____

Other notes:

____

____

End time (time of last measurement or observation before returning to shore):____________

Bull Kelp Survey Data Sheet (on shore)

Pre-Survey Section (on the beach)

Names of surveyors: Kelly Kelp, Peter Plankton, Amy Anemone

Location: North Beach

Date: 6/28/16 Weather conditions (circle one)

(Clear) Clouds Heavy rain Light rain Fog/mist

Tide height (ft): Start -0.5 Tide station: Port Townsend

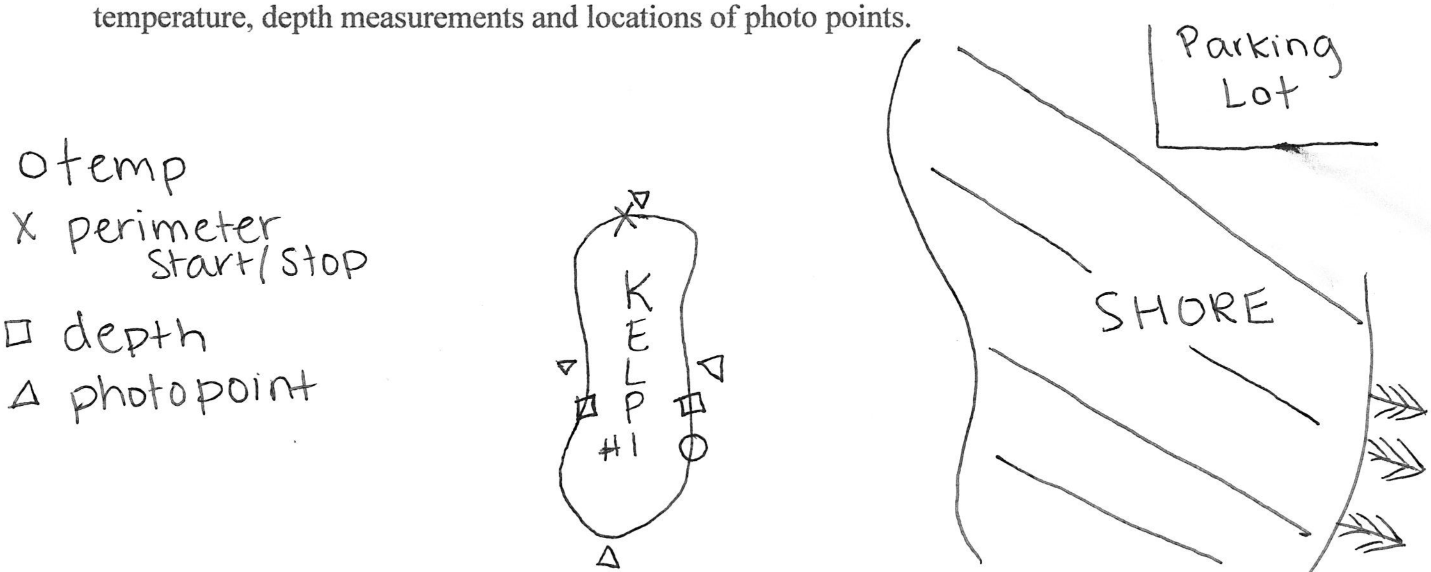
Current (knots): 0.3 kts Station/source: tidesmobilegeographics.com

Name of GPS unit or phone app Garmin etrex Accuracy of GPS: +/- 10 ft

☐ Proceed to page 2 to conduct survey. Following your survey, fill out Post-Survey section below.

Post-Survey Section (back on the beach after the survey)

Provide a sketch of the area surveyed, including approx. location of kelp bed boundary line, temperature, depth measurements and locations of photo points.



Post-survey checklist:

- ☑ Kelp bed perimeter track is saved in one or more GPS units
- ☑ GPS units are collected for storage until next survey
- ☑ Data sheets are <u>completely</u> filled out and legible.
- ☑ Photo points have been taken (and are later uploaded with properly labeled names)

Bull Kelp Survey Data Sheet (on the water)

Kelp Bed number or Name North Beach #1

Start time (time of temperature measurement): 14:30

Water Temp. (°C): 15

Depth (ft):

Edge closest to shore: 4.5 ft, GPS Point name: 001 Time: 14:37

Edge farthest to shore: 56 ft, GPS Point name: 002 Time: 14:50

Perimeter:

GPS point name at beginning of paddle around bed: 003

GPS perimeter track name: 20160628

GPS point name at end of paddle around bed: 004

Photo points: (take first photo, then immediately take a photo of this data sheet with the corresponding box checked off)

☑ **ToBe** ☑ **ToWa** ☑ **BeL** ☑ **BeR** ☐ **Volunteer photos**

Observations (consider density, animals present, overall health of blades, presence of understory kelp, human impacts, etc.): Healthy blades with minimal epifauna. Some boat damage to NW edge of bed. Understory Kelp present closer to shore. Perch and small schooling fish visible. SE edge of bed looks more dense since last survey (~10 bulbs/m vs. 3 bulbs/m)

Other notes:

Calm waters & a fun paddle! (Note to look at density in SE corner next time)

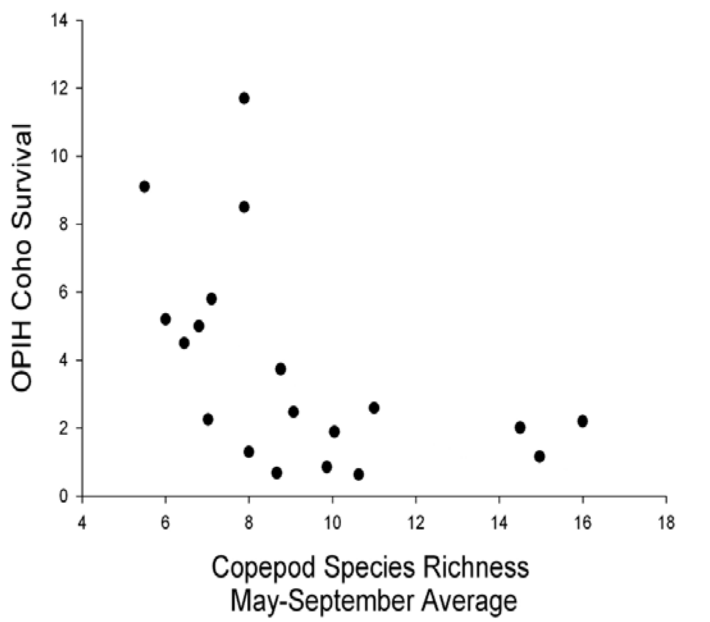
End time (time of last measurement or observation before returning to shore): 15:15

Zooplankton Sampling Protocol

Last updated by Julie E. Keister, 5 May 2014

These protocols are designed for monitoring zooplankton in Puget Sound for two different objectives: 1) To address how environmental variability affects Puget Sound's ecosystem through changes in zooplankton and 2) To measure how the prey field of salmon and other fish varies spatio-temporally and correlates with survival. The first type of sampling can be used to develop what is referred to in this document as "**Ecosystem Indicators**." The second type provides "**Prey Field Indicators**." Both have been used in other systems to understand how climate variability affects ecosystems and fish survival; indicators developed from both types of sampling have shown strong correlations to fish survival and have helped elucidate the mechanisms by which climate variability affects fish populations.

For example, the "**Ecosystem Indicator**" protocols are based on sampling off Oregon and Washington used by NOAA NWFSC to link climate variability to salmon survival through changes in zooplankton (e.g., [*Keister et al.*, 2011; *Peterson*, 2009; *Peterson and Schwing*, 2003]. The indices developed from this type of sampling strongly correlate with salmon returns and are used in NOAA's "Red-Light, Green-Light" forecasts of salmon returns (see http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ea-copepod-biodiversity.cfm). Another example of use of this type of zooplankton index comes from studies of cod survival in the North Sea ([*Beaugrand and Reid*, 2003; *Beaugrand et al.*, 2003] which revealed that an index of copepod species composition correlates with cod recruitment – larger copepod species dominate during cold climate regimes, which translates to higher growth (and thus survival and recruitment) of cod. These types of indices are powerful components of fish population forecasts. Similar indices can be developed in Puget Sound to add to our understanding of how environmental variability affects fish populations.



Relationship between survival of hatchery-raised coho salmon and copepod species richness off Oregon sampled by vertical net tows. The plot compares data from the summer that the fish entered the ocean. Coho return to their natal streams/hatcheries 18 months after entering the sea. Adapted from Peterson (2009).

The "Prey Field Indicator" protocols are based on sampling that Oregon State University and NOAA NWFSC uses to quantify juvenile salmon prey abundance to understand controls on juvenile salmon survival off Oregon and Washington. As part of the Bonneville Power Administration (BPA) project, prey field sampling off OR and WA has been conducted since 1998. An index of the zooplankton calculated from Bongo net sampling as described below correlate strongly with salmon growth and survival (C. Morgan, OSU, pers. comm.). The best station depth(s) to sample has not yet been determined and is under discussion and will depend upon initial sampling and analyses. Where capacity allows, sampling stations of several different station depths will help provide the data needed to refine these recommendations.

Monitoring protocols (see Field Methods below for more detail)

Equipment

***Ecosystem Indicator* sampling protocol: vertical tows**

- Bongo or ring net: 50-100 cm diameter (60-cm preferred), 150-212 µm mesh (200 µm preferred), 4:1 or 5:1 filtering ratio (i.e., length:width ratio – longer is better if boat can handle it). Cod end: 3.5-4.5" diameter x 6" length or larger (4.5' x 6" preferred), of same (preferred) or smaller mesh size.
- Flow meter, TSK style preferred. (See section below on flow meters.)
- Daytime sampling
- Vertical tow, sampled at a location that is ideally ~200 m water depth, or at the deepest location in the area.
- Lifted vertically from 5 m off bottom to the surface , deployed and immediately retrieved at 30 m/min. [hand-hauls will almost always be too slow]
- [For the SSMS Monitoring Program: 60-cm diameter ring net, 200 um mesh, 5:1 filtering ratio outfitted with TSK flow meter]

***Prey Field Indicator* sampling protocol: oblique tows**

- 60-cm bongos (preferred) or 1-m diameter ring net, 335 µm mesh.
- Black mesh nets (rather than the standard white).
- Cod end: 4.5" diameter x 12" length, of same (preferred) or smaller mesh size.
- Flow meter required (can be 'torpedo' style from SeaGear Corp or General Oceanics)
- Daytime tows
- Sampled at consistent locations of various water depths, TBD based on location, ideally 3 locations bracketing nearshore to deepest local spot (e.g., 30 m, 50 m, 100 m water depth) trying to sample over constant water depth during the whole tow when conditions allow (tow along a bathymetry contour).
- Towed over upper 30 m where depths are sufficient (net deployed until it is at 30 m depth, then immediately retrieved for a 'double-oblique' tow).
- Towed at 1.5 kts (minimum) to 2 kts, deployed and retrieved with a 30 m/min wire speed, optimally maintaining a 45º wire angle when possible. Adjust amount of line let out to accommodate for actual angle to achieve target depth (see Table below).
- [For the SSMS Monitoring Program: 60-cm diameter black bongo nets, 335 um mesh, outfitted with SeaGear flow meter]

1. Net description – Contact me for recommended vendors if needed

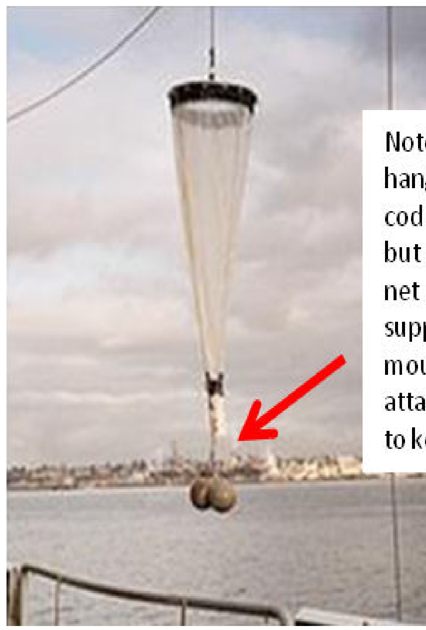
Ring and bongo (double ring) nets are described by their mouth diameter, mesh size, and their filtering ratio. Ring size is given in cm or m; mesh size in micrometers (microns, µm).

The filtration ratio is a description of the length-to-mouth ratio; the larger the filtration ration, the longer the net will be and the less likely the net will clog. We recommend 4:1 or 5:1 – higher is better, but if you work off a small boat, the shorter net is slightly easier to deploy, retrieve, and wash, but the downside is that it clogs more easily which results in a lower quality sample and more time rinsing the net.

The cod end is a removable durable plastic cylinder with holes cut in the sides that are covered with mesh of the appropriate size. The cod end should ideally be the same (or slightly smaller) mesh size as the net. If the mesh size of the cod end and the net disagree, record whichever mesh is larger as that will be the retention size.

Weighting the nets: Some weight added to the net is necessary to make the net sample correctly.

Vertical net with weights attached



Note that the weights hang slightly below the cod end when deployed, but are not pulling on the net or cod end, they are supported from the mouth ring and loosely attached to the cod end to keep it below the net.

Weighting vertical nets is typically done using a 3-string harness made of line. Tie the ends of the 3 lines to the upper net ring (not to the net or cod end itself), equidistant apart. *Make sure the weight lines are long enough to hang ~1 foot below where the cod end will hang when stretched*, tie the bottom ends of the cords to a metal O-ring to attach to the weight. With a small line, tie the cod end to the O-ring with plenty of slack to avoid pulling on the cod end when the weight lines are stretched (~1.5-2 feet of line). This will hold the cod end down near the weight to prevent tangling. *Be careful that the line to the cod end isn't so short that it will stretch the net toward the weight when deployed – that could rip the net. **The net and cod end should never feel the weight.** Attach weights to the O-ring before deployment. [Weighted cod ends are available, but aren't heavy enough to sink the net vertically except when it's very calm.]

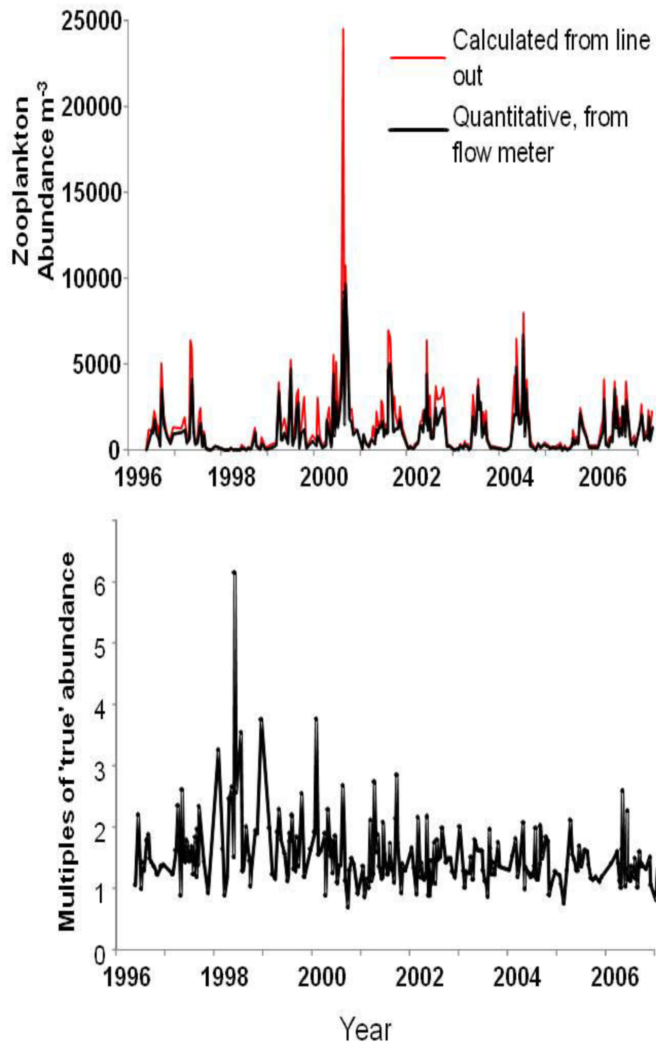
In calm weather with a vertically-lifted net, only enough weight to keep the cod end below the mouth of the net while dropping is needed (maybe 5 lbs). In rough conditions, if there's a strong wind or current, or if undertaking an oblique tow, more weight is needed (20+ lbs). The rougher the seas/current, the more weight that is necessary.

Weighting obliquely-towed ("horizontal") nets is done by attaching a weight to a mid-point on the rings with a short amount of line (e.g., center tow point of the bongo net frame). When lifted by the towing cable, the net opening should be about perpendicular to the deck. This will help the net sample with the mouth opening normal to the water. Rough seas, strong currents, or deeper tows may require more weight to help the net sink to the desired depth. 50+ lbs is not uncommon, but 30-35 lbs is typical.

2. Flow meters

A flow meter is ***absolutely necessary*** to provide quantitative abundance and biomass measures, especially for oblique tows (see plot below). The only exception is where vertical nets are used in shallow, calm waters. If your net always deploys with no net angle (perfectly vertically), then the mouth area x sampling depth can be used to calculate the water volume filtered. If there is any net angle, the net is towing and will sample more water; a flow meter is then required to quantify the volume filtered.

There are many types of flow meters available. However, only a few types are suitable for measuring flow through a vertically-towed net. For vertical tows, the preferred model is a TSK flow meter (http://www.tsk-jp.com/tska/contact.html), which is the only flow meter we've found that is reliably accurate on vertical tows. The problem with most flow meters is that they spin when being deployed (while the net is going down) and retrieved, but not equally in both directions. The TSK style has a 'back-stop' to prevent spinning when going down backwards and a 3-point attachment so they don't flip upside down on depolyment. They are also preferred because they are simple and heavy-duty (which makes for easier maintenance and very rare damage). However, the TSK style requires that the net is retrieved fast enough to depress the backstop and make the propeller spin (or inaccurately low readings will result). They can also be tricky to learn to read and can be costly (>$1000). Other brands are General Oceanics and SeaGear.net – those manufacturers make 'torpedo style' models with back-stops (e.g., SeaGear # MF315), but don't have a good way to mount them in the net mouth that prevents them from flopping over and spinning on deployment.



Without a flow meter, abundances are typically overestimated by ~1.5-2.5 times, occasionally 3-6 times. The overestimate is unpredictable, so can't be corrected for.

Torpedo style flow meters are preferred for oblique tows (e.g., SeaGear # MF315, ~$330, also see General Oceanics). No back-stop is needed for oblique tows.

Field Methods

- **Record** date, time, location, water depth, name of sampler, weather state, etc. on the field sheet.
- **Rig** the nets, attach weights, check equipment for holes, tangles, and loose fittings.
- **Reset** the flow meter to zero (TSK or SeaGear models) or record initial counts (other torpedo models).
- **Deploy** the net at 30 meters/min wire speed to desired depth. When at deepest depth, immediately retrieve the net at 30 m/min.
  For vertical nets, deploy at 30 m/min to 5 m from the bottom, or to a maximum of 200 m in deep water. Record the line angle and, if it's not perfectly vertical, increase the line out to achieve the target depth, calculating total line out to reach target depth from the wire angle (see table below). Retrieve immediately at 30 m/min. Visually check that the flow meter is spinning as it approaches the surface – if not, the retrieval rate may not have been fast enough or the flow meter needs inspection.
  For obliquely-towed nets, deploy to ~30 m depth (or 5-10 m off bottom in shallower water) with the boat moving at ~1.5-2 kts. Steadily let out line at 30 m/min, calculating the amount to let out based on angle (read from table below) to achieve 30 m depth, retrieve immediately at 30 m/min while the vessel is underway, maintaining ~45 degree line angle when possible. If wire angle is regularly >60 degrees, add more weight. For any particular boat, net, and current conditions, the goal is to adjust the total weight of the net (using added weights) needed to get that 45^{o} target angle at 1.5-2 kts ship speed—too little drag or too much weight on the net will cause the net to sample too deep; too much drag or too little weight will keep the net too shallow. This is something you may need to play with at first to optimize. Try not to decrease boat speed to <1.5 kts or strongly swimming organisms will be undersampled – instead, add more weight.
- **Retrieve** the net immediately upon reaching the surface (don't linger just below surface), taking care not to let the flow meter spin in the breeze if windy (note in the log if it does).
- **Rinse** the net downward from the outside using a seawater hose (ideally) or buckets and a hand held sprayer (such as a Spray Doc) to concentrate the sample in the cod end. Be fairly gentle so you don't destroy delicate critters during rinsing. Pay special attention to seams that catch organisms. Once you're satisfied on visual inspection that the plankton are all rinsed into the cod end, unhook it *being careful that it is not full to the top* – if it is, wait for it to drain, or open the cod end over a bucket, so you don't lose any sample, then strain the contents of the bucket through a sieve (or the cod end) to concentrate.
- **Concentrate the organisms in the cod end**, then pour and thoroughly rinse contents into a sample jar, using a funnel if necessary. Use the smallest jar necessary, but do not crowd the sample or it will not preserve well – if the biomass is thick (more than ½ of the jar volume) use a larger jar or split into two jars. Leave enough room for preservative.
  [Note: we've used 700 mL sample jars most often in Puget Sound, but sometimes a larger jar is necessary if ctenophores are dense, or the sample is full of phytoplankton and very slow to drain. Oblique tows may result in larger samples.]
- **Preserve** the sample using neutrally-buffered formalin, adding enough to make the final formalin concentration ~5% (i.e., add 35 ml of buffered formalin to a 700 mL sample jar containing your sample, top off to the threads with seawater to create a 5% formalin solution). It is handy (and safest) to use a dispensette, or a squeeze bottle with a

measured reservoir dispenser (these are great for this: http://www.usplastic.com/catalog/item.aspx?itemid=22892). Always top off the jar to the bottom of the threads with seawater to prevent dehydration. Close tightly and swirl to mix.

All personnel who handle formalin should be familiar with its dangers, protective equipment, and with what to do in case of a spill. Provide absorbent pads in case of spill and an MSDS (http://www.fishersci.com/ecomm/servlet/msdsproxy?productName=F79P4&productDescription=FORMALDEHYDE+ACS+POLY+4L&catNo=F79P-4&vendorId=VN00033897&storeId=10652).

Note: When you purchase formalin, it typically comes unbuffered. You need to add a buffer (we use Borax or baking soda) to bring it to a pH of ~8.2 (surface seawater pH). You can do this by adding the buffer in excess, mixing well, and letting sit for >24 hrs to saturate. The excess will precipitate out, which can get in the way of dispensing, so it's good to buffer in large containers (the original shipping bottles), then dispense into the squeeze dispensers after settling for >24 hrs. [Formalin is the same as 37% formaldehyde.]

- **Label** the jar (We usually write on the jar lid with a Sharpie if it is a matt surface (won't wipe off), or on a label stuck on the side of the jar) with Project, Date, Time, Station name/number, Net mesh size, Net ring size, type of tow (vertical or oblique), depth of tow, and flow meter reading. It is preferable to also make a label for the inside of the jar (in case the outside label gets wiped off, or lids switched accidentally, etc) using waterproof paper and pencil. Label the same things as the lid, plus the lat/long of the station sampled if it is not a consistent location.
  [Note that for the SSMSP Monitoring, it is sufficient to label the jar with: SSMSP, date, station, type of tow (vertical or bongo), flow meter reading) if a field sheet is also filled out.
- Complete the **field sheet** for the station, recording the flow meter reading and wire angle. Note anything unusual about the sampling.

Analysis protocols

The Ecosystem Indicator samples must be analyzed by an expert zooplankton taxonomist. Protocols for analyzing the Prey Field Indicator samples will be provided on request once time series are established.

Acknowledgments

These protocols were written in collaboration with experts in Oregon and British Columbia (W. Peterson (NOAA), C. Morgan (OSU), M. Trudel (DFO)) who have established zooplankton monitoring programs.

Studies cited

Beaugrand, G., K. M. Brander, J. A. Lindley, S. Souissi, and P. C. Reid (2003), Plankton effect on cod recruitment in the North Sea, *Nature*, *426 (6967)*, 661-664, 10.1038/nature02164

Beaugrand, G., and P. C. Reid (2003), Long-term changes in phytoplankton, zooplankton and salmon related to climate, *Global Change Biol.*, *9 (6)*, 801-817,

Keister, J. E., E. Di Lorenzo, C. A. Morgan, V. Combes, and W. T. Peterson (2011), Zooplankton species composition is linked to ocean transport in the Northern California Current, *Global Change Biol.*, *17 (7)*, 2498-2511, 10.1111/j.1365-2486.2010.02383.x

Peterson, W. T. (2009), Copepod species richness as an indicator of long-term changes in the coastal ecosystem of the northern California Current, *CalCOFI Reports*, *50*, 73-81,

Peterson, W. T., and F. B. Schwing (2003), A new climate regime in northeast Pacific ecosystems, *Geophys. Res. Lett.*, 30 (17), doi:10.1029/2003GL017528

Wire Angle Table: Match the wire angle with target depth to determine how many meters of line to put out.

Wire angle →	5	10	15	20	25	30	35	40	45	50	55	60
Target depth (m) ↓												
5	5	5	5	5	6	6	6	7	7	8	9	10
10	10	10	10	11	11	12	12	13	14	16	17	20
15	15	15	16	16	17	17	18	20	21	23	26	30
20	20	20	21	21	22	23	24	26	28	31	35	40
25	25	25	26	27	28	29	31	33	35	39	44	50
30	30	30	31	32	33	35	37	39	42	47	52	60
35	35	36	36	37	39	40	43	46	49	54	61	70
40	40	41	41	43	44	46	49	52	57	62	70	80
45	45	46	47	48	50	52	55	59	64	70	78	90
50	50	51	52	53	55	58	61	65	71	78	87	100
55	55	56	57	59	61	64	67	72	78	86	96	110
60	60	61	62	64	66	69	73	78	85	93	105	120
65	65	66	67	69	72	75	79	85	92	101	113	130
70	70	71	72	74	77	81	85	91	99	109	122	140
75	75	76	78	80	83	87	92	98	106	117	131	150
80	80	81	83	85	88	92	98	104	113	124	139	160
85	85	86	88	90	94	98	104	111	120	132	148	170
90	90	91	93	96	99	104	110	117	127	140	157	180
95	95	96	98	101	105	110	116	124	134	148	166	190
100	100	102	104	106	110	115	122	131	141	156	174	200
105	105	107	109	112	116	121	128	137	148	163	183	210
110	110	112	114	117	121	127	134	144	156	171	192	220
115	115	117	119	122	127	133	140	150	163	179	200	230
120	120	122	124	128	132	139	146	157	170	187	209	240
125	125	127	129	133	138	144	153	163	177	194	218	250
130	130	132	135	138	143	150	159	170	184	202	227	260
135	136	137	140	144	149	156	165	176	191	210	235	270
140	141	142	145	149	154	162	171	183	198	218	244	280
145	146	147	150	154	160	167	177	189	205	226	253	290
150	151	152	155	160	166	173	183	196	212	233	262	300
155	156	157	160	165	171	179	189	202	219	241	270	310
160	161	162	166	170	177	185	195	209	226	249	279	320
165	166	168	171	176	182	191	201	215	233	257	288	330
170	171	173	176	181	188	196	208	222	240	264	296	340
175	176	178	181	186	193	202	214	228	247	272	305	350
170	171	173	176	181	188	196	208	222	240	264	296	340
180	181	183	186	192	199	208	220	235	255	280	314	360
185	186	188	192	197	204	214	226	242	262	288	323	370
190	191	193	197	202	210	219	232	248	269	296	331	380
195	196	198	202	208	215	225	238	255	276	303	340	390
200	201	203	207	213	221	231	244	261	283	311	349	400

Reading a TSK flow meter:

Before using the flow meter, please study these instructions carefully. Misread flow readings are remarkably common and result in big errors in abundance and biomass calculations.

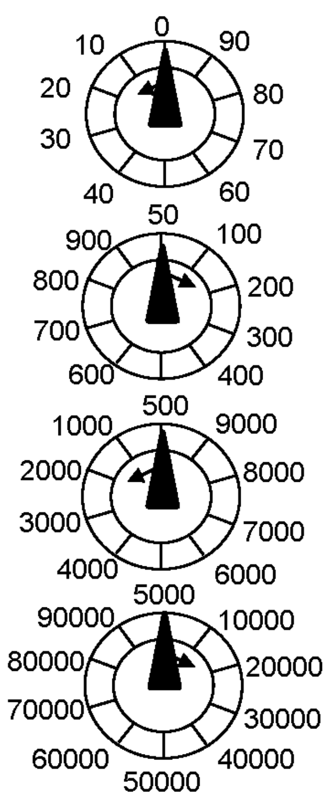
The TSK flow meter uses opposing gears that all rotate continuously when the propeller spins. There are several points to know to read them accurately.

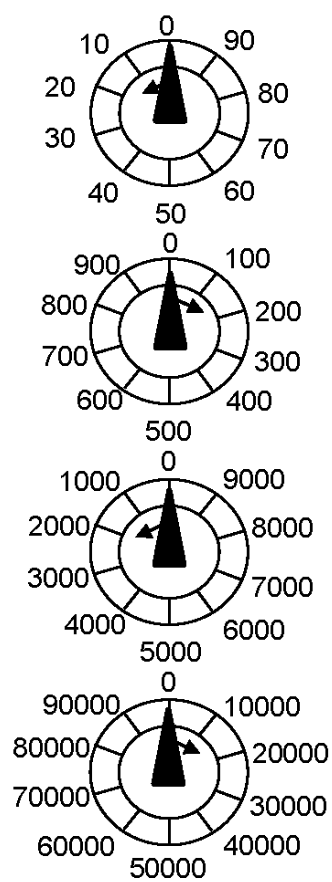
1) The flow meter should be reset PERFECTLY to zero on all dials before each deployment as shown below (rotate dials up to 0 by hand).

2) Although the meter shows the dial numbering on the LEFT below, they should show the numbering as on the RIGHT (note the added 0s at the zero position of each dial). I.e., each dial starts at 0 and rotates continuously toward higher numbers.

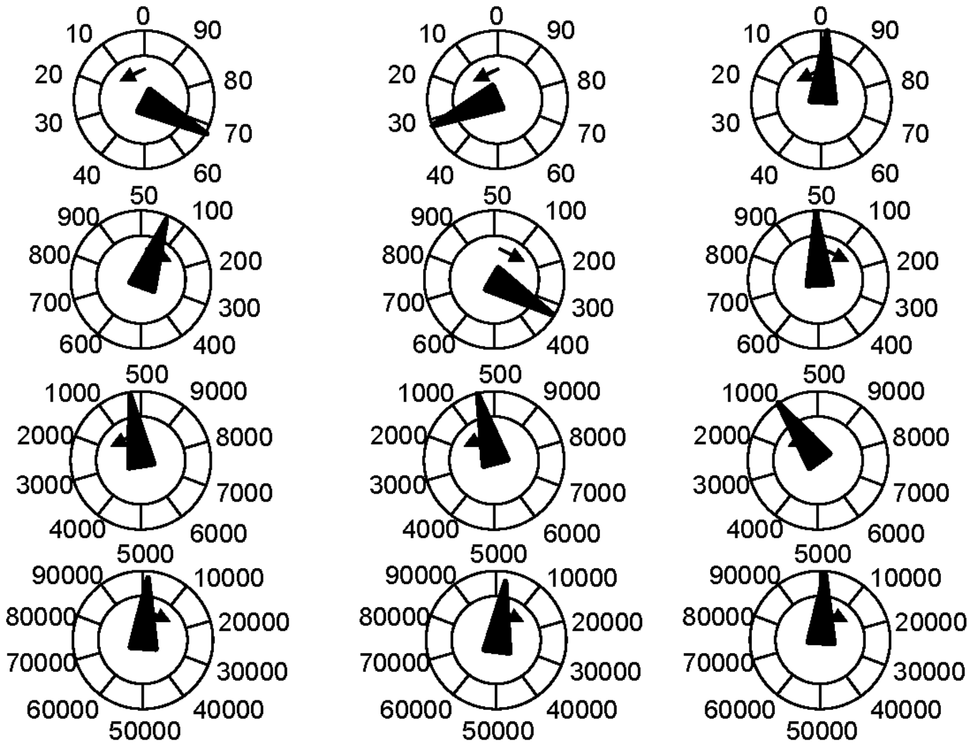
3) Start by reading the bottom dial and work up. See examples on next page. Because dials rotate continuously, every dial will show some reading after a tow, but a dial doesn't "count" until it's gone at least *past* its first tick (past 10 on the first dial, past 100, etc.). You will rarely if ever get a reading from the bottom dial: most readings for vertical tows will be between 100-1500 revolutions.

4) Procedurally, the net must be lifted at a fast enough rate for the flow to depress the backstop. If you get anomalously low readings compared to normal, then try to watch for a spinning propeller when retrieving. Always record the serial number (on outer flap) once per trip to match with the calibration.





Some examples:



68 revs. | **332 revs.** | **999 revs.**

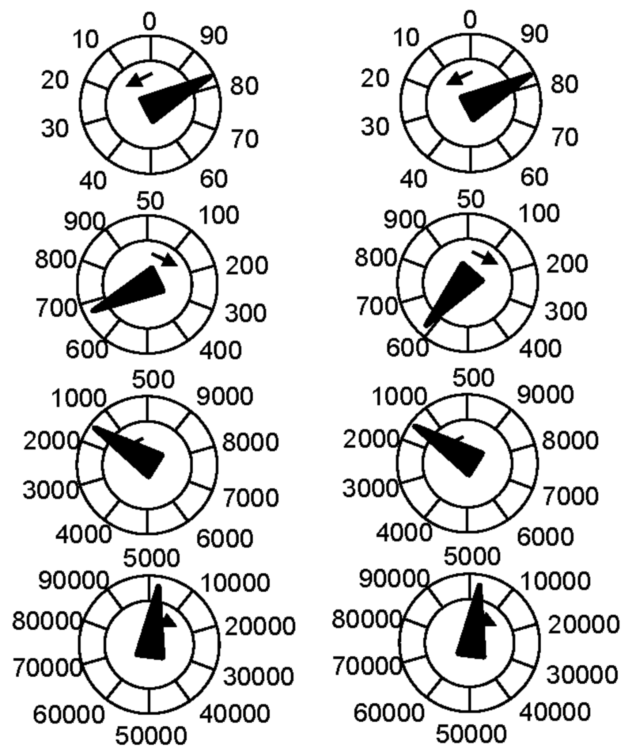
IMPORTANT -- Note these two slightly different readings.

The one on the *left* is **1682**.

But the reading on the *right* is <u>not possible</u> and means that <u>the dials were not all perfectly zeroed before deployment</u>.

What's wrong with it? The top two dials are inconsistent – for a reading of 82 on the top dial to be correct, the reading on the 2nd dial should either be *almost* to the 600 or *almost* to the 700, not just past 600.

So what's the correct reading? That's very hard to tell, and emphasizes the importance of zeroing perfectly to begin with. In this case, the higher-order dial is probably the one that's off because it would be caused by a smaller mistake when zeroing I.e., the actual reading is probably **1582**. You will have to use some judgment when there's an error like this, so it's best to draw the dial positions on the log sheet and interpret in whichever way is *most likely* given other readings for similar tow depths and the smallest probably zeroing error.



1682 | **1???**

SSMSP Zooplankton Monitoring

Collecting group:_________________________ **Collector names:**______________________________

Collection Date:__________________________ **Transect:**_____________________________

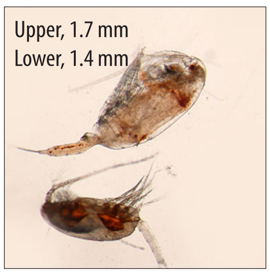
Gear type:	**Bongos** 60-cm, 335-µm	**Bongos** 60-cm, 335-µm	**Bongos** 60-cm, 335-µm	**Vertical** 60-cm, 200-µm
Station ID				
Latitude				
Longitude				
Time				
Station Depth (m)				
Wire out (m)*				
Wire angle on retrieval*				
Flow meter reading – start	______revs	______revs	______revs	______revs
Flow meter reading - end	______revs	______revs	______revs	______revs
Weather / sea state and winds:				
Comments:				

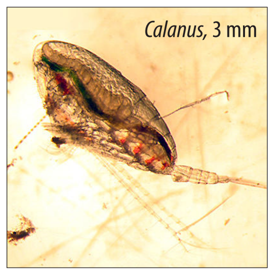
*Adjust line put out using wire angle table. Record wire angle while bringing in. For vertical nets, indicate angle off 0 (straight up and down).

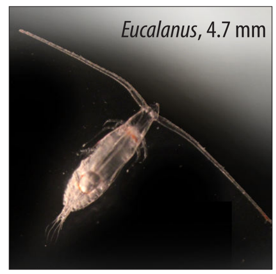
Marine Zooplankton of Puget Sound

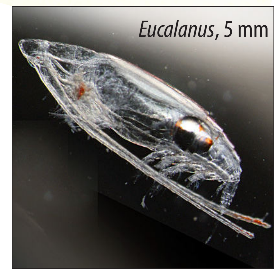
This identification card includes most groups of marine zooplankton found in Puget Sound. Size ranges provided are approximate - some specimens may be outside of the stated ranges. Exact measurements for specimens in photos are provided where available.

Copepods 0.5-5 mm


Upper, 1.7 mm
Lower, 1.4 mm

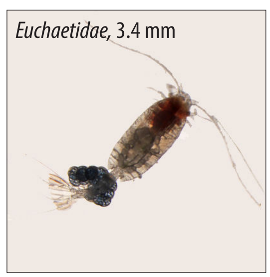

Calanus, 3 mm


Eucalanus, 4.7 mm


Eucalanus, 5 mm


Centropages, 2 mm


Oithona, 1 mm


Euchaetidae, 3.4 mm

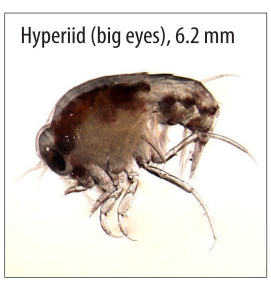
Cladocerans (water fleas) ~1 mm


Evadne


Podon

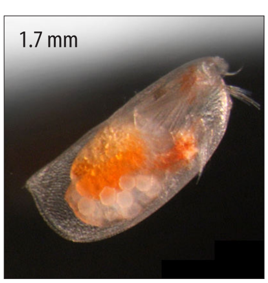
Amphipods 0.5-2 mm


Gammarid (small eyes)


Hyperiid (big eyes), 6.2 mm


6.3 mm

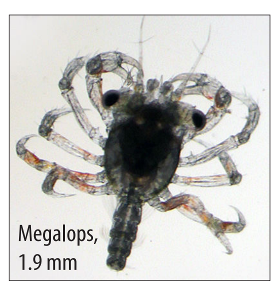
Ostracods 0.5-2 mm


1.7 mm

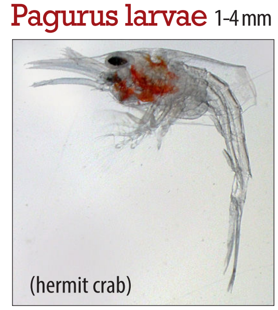
Crab larvae 2-5 mm


Zoea, 3.7 mm

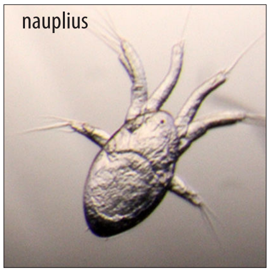

Zoea, 3.2 mm

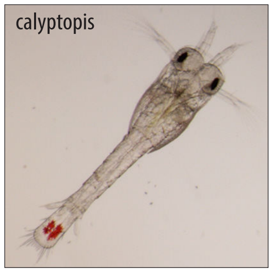

Megalops, 1.9 mm

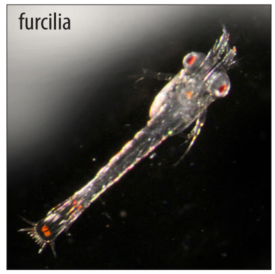
Pagurus larvae 1-4 mm


(hermit crab)

Euphausiids (krill) nauplius ~ 0.5 mm; calyptopis 0.5 mm-1.5 mm; furcilia 2-5 mm; adults 8-15 mm


nauplius

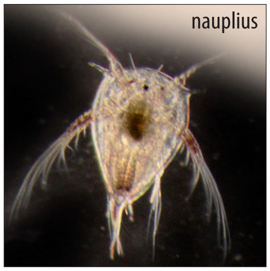

calyptopis

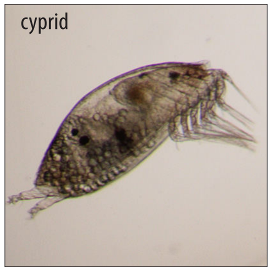

furcilia

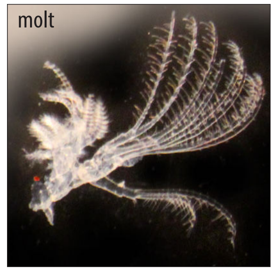

adult

All photos by Audrey Djunaedi, except *Calanus* provided by Julie Keister; larvacean provided by NOAA Photo Library; fish larva provided by Sarah Norberg, NWFSC, NOAA. Special thanks to Julie Keister and Audrey Djunaedi for advising on content and providing size information.

Barnacles (larvae and adult molt) larvae 0.5-1 mm; molt size varies


nauplius


cyprid

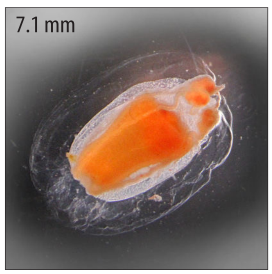

molt

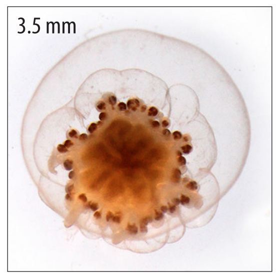
Sea Grant Washington

Washington Sea Grant
University of Washington
3716 Brooklyn Avenue NE
Seattle, WA 98105-6716
206.543.6600
WSG-AS 13-07
www.wsg.washington.edu

Jellies

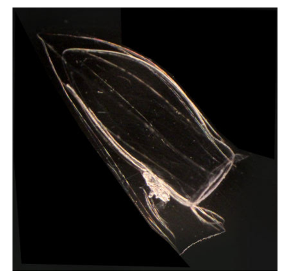

Eutonina indicans


7.1 mm

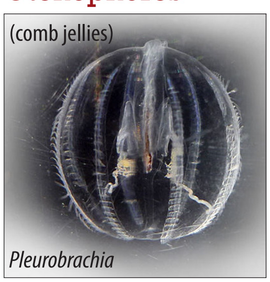

3.5 mm


4.8 mm

Siphonophores 4-8+ mm



Ctenophores

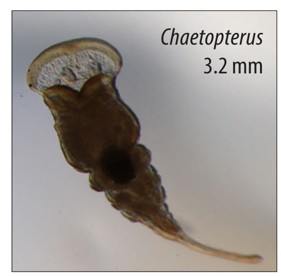

(comb jellies)
Pleurobrachia

Polychaete worms 1 mm-50 cm


3.4 mm


3.7 mm


2.5 mm

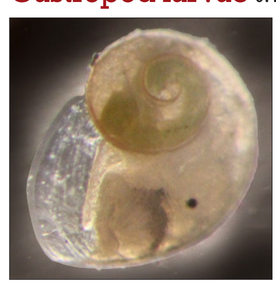

Chaetopterus
3.2 mm

Chaetognaths (arrow worms) 3-40 mm

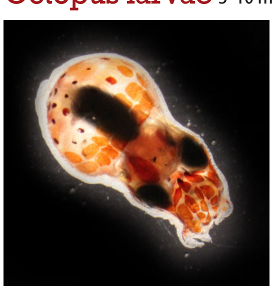
Pteropods 0.1-3 mm


Limacina

Gastropod larvae 0.1-0.8 mm



Octopus larvae 3-10 mm



Cyphonautes height ~0.6 mm

Larvaceans 2-4 mm

Fish larvae