Journal of
Plankton Research

plankt.oxfordjournals.org

J. Plankton Res. (2015) 37(1): 21–27. First published online November 6, 2014 doi:10.1093/plankt/fbu101

SHORT COMMUNICATION

A vocabulary for the configuration of net tows for collecting plankton and micronekton

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Received August 13, 2014; accepted October 14, 2014

Corresponding editor: Roger Harris

Collection of zooplankton is done using a wide array of instrumentation. To ensure the long-term value of zooplankton data, metadata about what the data are and when, where, and how the data were collected, plus the use of a domain-specific, controlled vocabulary is essential. It is especially important to use a controlled "deployment" vocabulary when plankton nets are used to collect data, and here we present a vocabulary of net deployment terms.

KEYWORDS: net tow types; plankton; controlled vocabulary; metadata

Scientific communities involved in geoscience research including oceanography are now in a new era in which it is expected that data generated in the course of research are made publically available. In the USA, European Union and other countries, investigators who have received federal funds are required to submit primary data, samples, physical collections and other supporting materials to an appropriate data center or repository (NSF11060, 2011; European Commission, 2012). As a result, the oceanographic data management community is actively working to identify best practices for a curation framework that will enhance the value of historical and newly collected data and information. Data accuracy, discoverability and availability are fundamental to a successful data management framework, while complete metadata is at the foundation of successful implementation of such a framework. The information about what the data are and when, where, and how the data were collected is essential for single investigators and collaborative groups of investigators to record to enable data reuse and repurposing beyond the initial intent of the collector(s) of the original data. Also essential are controlled vocabularies and ontologies that enable data interoperability, advanced search and discovery (Leadbetter *et al.*,

Table I: Types of net tow deployments and examples of nets using the deployment methods

Tow type number	Net tow type	Description	Net examples
1	Single net or net pair vertical tow (Fig. 1(1))	The sample is collected between a deeper depth and the surface from a stationary platform; the net is typically lowered to depth and samples on the way up while the gear is being hauled back to the surface. Vertical tows collect vertically integrated samples. No closing mechanism is used.	WP-2, Hensen Net, Bongo net, other non-opening–closing nets (Wiebe and Benfield, 2003, Plate s 1 and 2).
2	Single net reverse vertical tow	A particular kind of single net vertical tow deployment where the net goes down open, starting at the surface, samples on the way down, and closes at depth either via a choke rope or a messenger system.	Includes pop-down nets like the free-fall net, and the Heron net (Wiebe and Benfield, 2003, Plate 10).
3	Single net or net pair vertical sub-surface tow (Fig. 1(3))	A closing mechanism or both an opening and closing mechanisms are present and used to sample a single depth interval from a stationary platform. With a single messenger, the net is deployed to a particular depth, hauled to a shallower depth, and a messenger is sent down to close the net. A double messenger system avoids contamination on the way down by lowering the net closed, a messenger is dropped to open it, and the net is hauled to a second depth and another messenger is sent to close it.	Opening–closing nets (messenger, pressure release, timer release—Wiebe and Benfield, 2003, Plates 6 and 8).
4	Single net reverse vertical sub-surface tow	The net goes down closed and mouth first from a stationary platform. When the net is at predetermined depth, one method has a messenger sent down that opens the net. The net continues to drop with the mouth open until a second messenger is sent to close the mouth. The net is then retrieved closed with the sample in the cod-end. A plummet net can be configured in this way. Other methods have been used to open and close nets during this kind of net deployment.	Includes pop-down nets such as the Plummet net, streamer net, and others (Wiebe and Benfield, 2003, Plate 10).
5	Single net or net pair surface tow	A particular kind of horizontal tow where the net samples the upper ocean layer close to the surface and not including the air above the water. Once deployed, the gear is towed horizontally at one depth.	WP-2, Hensen Net, Bongo net, other non-opening–closing nets (Wiebe and Benfield, 2003, Plates 1 and 2).
6	Neuston net tow	Net deployments designed to collect animals or debris floating on the surface or in the upper few centimeters of the water from a moving platform. The net is towed horizontally at one depth and samples half in and half out of the water. Occasionally, Neuston nets can be stacked vertically in the water column to sample as deep down as 100 cm.	See Wiebe and Benfield (Wiebe and Benfield, 2003, Plates 20 and 21).
7	Single net or net pair oblique tow (Fig. 1(7))	This deployment type has sometimes been misrepresented as a double oblique. A true double-oblique tow (see below) is in the form of a W. For a single-oblique tow, the net fishes from the surface obliquely down to some particular depth and back to the surface along a V-shape path. There is no opening–closing mechanism. Most of the time, oblique tows are not symmetrical. The net is typically shot to depth rapidly and hauled to the surface more slowly.	Ring-nets, Bongo nets, Tucker Trawls, other non-opening–closing nets (Wiebe and Benfield, 2003, Plates 2 and 3).
8	Single net or net pair double-oblique tow (Fig. 1(8))	A single net or net pair is deployed open from a moving platform to a predetermined depth. It is then returned to the surface (always open). Without returning the net to the deck, the net starts down again and fishes to the predetermined depth (usually the same depth as the first). If this down/up pattern is repeated more than twice without returning the net to the deck, it becomes a towyo (see 9). This technique is ideal for long-integrated tows, i.e. for catching patches of zooplankton.	Ring-nets, Bongo nets, Tucker Trawls, other non-opening–closing nets (Wiebe and Benfield, 2003, Plates 2 and 3).
9	Single net or net pair towyo	A single net or net pair is deployed open from a moving platform to a predetermined depth and then repeatedly hauled to the surface and sent back to depth.	Ring-nets, Bongo nets, Tucker Trawls, other non-opening–closing nets (Wiebe and Benfield, 2003, Plates 2 and 3).
10	Single net or net pair oblique–horizontal tow (Fig. 1(10))	The sample is collected between two depths along a U-shape path from a moving platform; the sample is collected while the device is lowered from the surface down to a target	Ring-nets, Bongo Nets,Tucker, Trawls, IKMT, or other non-opening–closing

Continued

Table I: Continued

Tow type number	Net tow type	Description	Net examples
		depth, towed horizontally for a given time at that depth, and then hauled back to the surface. Also called U-shape tow.	nets (Wiebe and Benfield, 2003, Plates 2 and 3).
11	Single net or net pair oblique-stepped–horizontal tow (Fig. 1(11))	Single net or net pair towed continuously in a stepped horizontal fashion. The sample is collected while the gear is towed from depth to the surface in a succession of horizontal and oblique steps; details related to sampling time at specific depths and the duration of the tow should be included in the cruise metadata. It has also been called a "stepped oblique tow".	Ring-nets, Bongo Nets, Tucker, Trawls, IKMT or other non-opening–closing nets (Wiebe and Benfield, 2003, Plates 2 and 3).
12	Single net or net pair horizontal tow (Fig. 1(12))	The sample is collected within a defined depth stratum from a moving platform; the depth of the tow is controlled by the weight of the device, the length of the wire, and the towing platform speed. Horizontal tows collect horizontally integrated samples. Requires either an opening and closing system or the ship must be stopped during deployment and recovery. Otherwise, it becomes an oblique–horizontal tow.	Examples include Clarke–Bumpus net, Leavitt Net or other opening and closing nets or meter nets deployed and recovered with platform stopped.
13	Single net stratified-oblique tow (Fig. 1(13))	An opening and closing mechanism is present and a single depth interval is sampled by a single net from a moving platform. The net is sent down closed, opened by messenger, and fished upward at a certain rate. At a predetermined depth, another messenger is sent down to close the nets. A variation on this is to open the net by messenger and close by flow meter readings.	Clarke–Bumpus net, Leavitt net, other opening–closing nets (Wiebe and Benfield, 2003, Plates 6 and 8).
14	Multiple nets stratified-oblique tow (Fig. 1(14))	Two or more nets are on the wire at the same time. The nets are sent down closed, opened by messenger, and fish upward at a certain rate. At a predetermined depth, another messenger is sent down to close the nets. A variation on this is to open the nets by messenger and close by flow meter readings.	Clarke–Bumpus net, Leavitt net, other opening–closing nets (Wiebe and Benfield, 2003, Plates 6 and 8).
15	Multiple nets stratified-horizontal tow (Fig. 1(15))	Two or more nets are on the wire at the same time. The ship is standing or moving ahead slowly. The nets are always open. Wire is paid out slowly and the nets attached while paying the wire out. When the proper amount of wire has been paid out, the vessel is brought to towing speed. At the completion of the tow, the ship is stopped and the nets are recovered. Figure redrawn from Miller (Miller, 1961).	Clarke–Bumpus net, Leavitt net, other opening–closing nets, or Miller High Speed Sampler Non-opening–closing (Wiebe and Benfield, 2003, Plates 6, 8 and 14).
16	Multiple net system vertical stratified tow (Fig. 1(16))	Multiple nets are deployed on a single frame with opening and closing capabilities. The ship is stopped. The nets are sent down closed, and opened and closed one at a time as the nets are hauled back to the surface. This is done electrically or with pressure releases	Be Net, Multinet (pressure release, electronic release).
17	Multiple net/multiple cod-end system stratified-oblique tow (Fig. 1(17))	Multiple nets are deployed on a single frame with opening and closing capability. In the case of a system like MOCNESS, the first net (0) is deployed to the bottom depth, open. Once at the bottom, the zero net is closed, at the same time opening the second net (net 1). This net is hauled to a predetermined depth and then closed while the next net is opened. The procedure continues until the final predetermined depth is reached (normally the surface). For systems, like the Multinet, the system can be deployed without a net open and the first net is opened at depth. This deployment strategy can also be done with a single net with a multiple cod-end system (Redrawn from Wiebe *et al.*, 2013, Fig. 4).	MOCNESS, BIONESS, Multinet, other multiple net opening–closing systems (Wiebe and Benfield, 2003, Plates 28–31).
18	Multiple net/multiple cod-end system or CPR horizontal tow (Fig. 1(18))	Multiple nets are deployed on a single frame with opening and closing capability, or a single net with a multiple cod-end system, or a CPR. In the case of a system like MOCNESS, the first net (0) is deployed to a predetermined depth, open. Once at that depth, that net is closed, at the same time opening the second net (net 1). Net 1 and all subsequent nets are opened–closed at the depth selected for the horizontal tow. For systems, like the Multinet, the system can be deployed without a net open and the first net is	MOCNESS, BIONESS, Multinet, multiple net opening–closing systems; Cod-end Serial Samplers LHPR, Aries; CPR (Wiebe and Benfield, 2003, Plates 19, 27–31).

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Table I: Continued

Tow type number	Net tow type	Description	Net examples
		opened at the selected depth. The CPR is normally towed horizontally just below the sea surface and samples plankton on a single slow-moving band of silk that is then spooled in a storage tank until recovery.	
19	Multiple net/multiple cod-end system oblique–horizontal towyo (Fig. 1(19))	Multiple nets are deployed on a single frame with opening and closing capability. In the case of a system like MOCNESS, the first net (0) is deployed to a predetermined depth, open. Once at that depth, that net is closed, at the same time opening the second net (net 1). This net is hauled back to a predetermined shallower depth open and then closed and the next net is opened and sent back to the same depth as the original net and closed and the next net opened etc. This continues until all the desired sampling is accomplished. Also called "sawtooth tow." For systems, like the Multinet, the system can be deployed without a net open and the first net is opened at depth. This deployment strategy can also be done with a single net with a multiple cod-end system (Fig. 1(19) Redrawn from Wiebe, *et al.*, 1992, Fig. 3).	MOCNESS, BIONESS, Multinet, other multiple net opening–closing systems (Wiebe and Benfield, 2003, Plates 28–31).
20	Multiple net/multiple cod-end system stratified-oblique–horizontal towyo (Fig. 1(20))	Multiple nets are deployed on a single frame with opening and closing capability. In the case of a system like MOCNESS, the first net (0) is deployed to a predetermined depth, open. Once at that depth, that net is closed, at the same time opening the second net (net 1) net. On the oblique section up, several different depth intervals are sampled by successive nets. Once at the shallowest point of tow (usually the surface), the next net is open and shot open down to depth. Then this net is closed and again on the way up, several different depth intervals are sampled by successive nets. For systems, like the Multinet, the system can be deployed without a net open and the first net is opened at depth. Sampling depths can be adjusted as the environmental structure requires. This deployment strategy can also be done with a single net with a multiple cod-end system (Fig. 1(20) Redrawn from Wiebe, *et al.*, 1992, Fig. 2).	MOCNESS, BIONESS, Multinet, other multiple net opening–closing systems (Wiebe and Benfield, 2003, Plates 28–31).
21	Multiple net/multiple cod-end system oblique-stepped (continuous) horizontal tow (Fig. 1(21))	Multiple nets are deployed on a single frame with opening and closing capability. The first net (0) is deployed to a predetermined depth, open. Once at that depth, that net is closed, at the same time opening the second net (net 1). This net is towed horizontally for some distance then quickly hauled to some shallower depth (2) where the net is closed and the next net is open. That net is then towed horizontally for some distance then hauled quickly to some shallower depth and closed, the next net open and so on until all the nets have been fished horizontally over a series of fixed depths. This deployment strategy can also be done with a single net with a multiple cod-end system.	MOCNESS, BIONESS, Multinet, other multiple net opening–closing systems (Wiebe and Benfield, 2003, Plates 28–31).
22	Multiple net/multiple cod-end system stepped discontinuous horizontal tow (Fig. 1(22))	Multiple nets are deployed on a single frame with opening and closing capability or a single net with a multiple cod-end system. The net system is deployed to a predetermined depth with the first net either open or closed. At depth, the first net is opened (if it was closed) or closed (if it was open) and the next net opened in this case. The open net is towed horizontally for some distance and then closed. The next net is NOT open upon the previous net's closing and the system travels some distance at the same depth before another net is opened. This sequence continues until all nets are fished at the specific required depth intervals. In this deployment configuration, there are intervals between nets that are NOT sampled.	MOCNESS, BIONESS, Multinet, multiple net opening–closing systems; Cod-end Serial Samplers LHPR, Aries (Wiebe and Benfield, 2003, Plates 27B, C-31).
23	Multiple net system oblique-stepped	Multiple nets are deployed on a single frame with opening and closing capability. The net system is deployed to a predetermined depth with the first net either open or	Note: This kind of tow has been done using the "Macroplankton trawl" (Krafft, *et al.*, 2010) to catch

Continued

Table I: Continued

Tow type number	Net tow type	Description	Net examples
	discontinuous horizontal tow (Fig. 1(23))	closed. At depth, the first net is opened (if it was closed) or closed (if it was open) and the next net opened in this case. The open net is towed horizontally for some distance and then closed. The next net is NOT open upon the previous net's closing. The net system is raised to another predetermined depth and the next net is open and fishes for some distance/time. That net is then closed again without opening the next net and raised to a new depth. The next net is opened at that depth, fishes horizontally for some distance/time and is then closed. This sequence continues until all nets are fished at the specific required depth intervals. In this deployment configuration, the intervals between depths are NOT sampled.	macroplankton/nicroneckton. It is a fine-meshed plankton trawl having a 38-m^2 mouth opening, a mesh size of 3 mm from the trawl-opening to the rear end, and a MultiSampler unit at the rear with five places for cod-ends, but only equipped with three, thus allowing for the gaps between collections.
24	Epibenthic plankton tow	A net system deployed from a ship, a sled, a towed body, an ROV, or a DSRV. Most have opening and closing capability, especially if towed from a ROV or DSRV. Those towed from sleds originally did not have opening and closing capability in the beginning, but were modified later to collect discrete samples. Usually horizontal tows, the sample or samples is/are collected while the gear is towed along the bottom of the sea and upward to 100 m above the bottom. These systems are designed to avoid catching sediment and associated bottom fauna	See Wiebe and Benfield (Wiebe and Benfield, 2003, Plates 6, 8 and 14).

See Fig. 1 for schematic drawings of some of the net tow types. Each net tow type in this table has been attributed a unique and persistent Uniform Resource Identifier (URI) in the NERC Vocabulary Server enabling direct access to the full record including unique identifier, main title, alternative title and definition (see http://vocab.nerc.ac.uk/collection/B07/current/).

2014), and the linking of existing data repositories and networks (Alexander, 2011).

Widely used community vocabulary terms have been aggregated and are served by the National Environmental Research Council (NERC) Vocabulary Server v2.0 (http://www.bodc.ac.uk/products/web_services/vocab/). Included are terms in the SeaDataNet Device Catalogue (http://seadatanet.maris2.nl/v_bodc_vocab_v2/search.asp?lib=L22). The standard vocabulary for nets found there is based on the review of net systems that have been used since the late 1800s (Wiebe and Benfield, 2003). An intercomparison study of a number of currently used nets to collect plankton was most recently published by Skjoldal *et al.* (Skjoldal *et al.*, 2013). Missing from the literature is a systematically compiled and published vocabulary of net deployment terms, without which any collection of essential information about plankton nets and the data collected from them would be incomplete. The objective of this short communication is to provide the basis for a controlled vocabulary of net deployment terms for inclusion in the NERC Vocabulary Server at the British Oceanographic Data Centre.

Inherent in a standard net system deployment vocabulary is a description of the net trajectories used in the deployment of nets from ships or other platforms. How is each kind of net deployed to achieve the desired collection? The gear types are coupled to deployment descriptions because the kind of gear being deployed determines the kind of deployment that is possible. Thus, the description of the data collected requires using both vocabularies. Similarly, the results may not be intercomparable and repeatable unless both the net and deployment methodologies are as used previously.

A large variety of nets have been used to collect plankton and micronekton (Wiebe and Benfield, 2003). They have different size mouth openings, different mesh sizes, and different capabilities to be used either in non-opening–closing mode, closing mode, or opening–closing mode. In addition, there are systems of nets on a single frame that can be opened and closed either by messenger release or electrically, i.e. multiple net systems. All of this information constitutes the metadata that are needed to describe the sampling system. Some systems are designed to sample the mid-water column and some are designed to sample the sea surface or within a few meters of the sea bottom. Those for the water column can sample either upward or downward. A number of the different deployment methods have been employed to collect plankton and micronekton (Table I; Fig. 1). The "Net Tow Type" column in Table I constitutes the defined vocabulary of net deployment terms.

Single nets or a net pair (e.g. Bongo or paired WP2 net) with a simple mouth opening and no mechanism

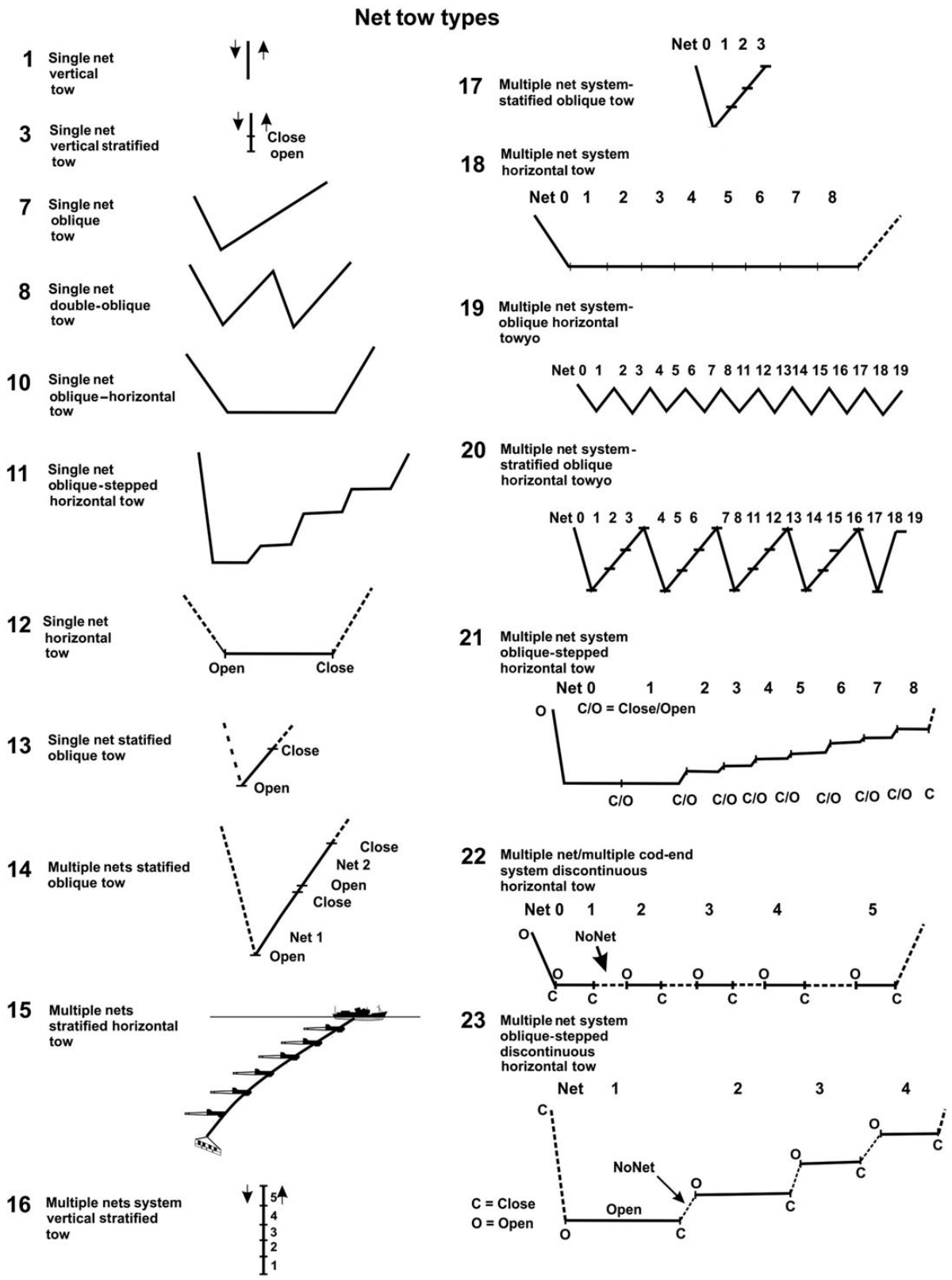

Fig. 1. Schematic drawings of net tow deployment types. The numbers refer to the deployment descriptions presented in Table I. Note: Not all of the deployment types are illustrated in this figure. Dashed lines indicate when no net is open.

for opening or closing have a number of deployment strategies (Table I, tow types 1, 5–11). They are often deployed vertically downward from a stationary platform and then hauled to the surface to collect plankton on the upward portion of the tow. They may also be deployed open from a slowly moving vessel to a maximum depth and then hauled back to the surface in an oblique tow (this tow has sometimes been called a double-oblique tow). They can also be deployed quickly to depth, towed horizontally either at a particular depth or over some depth interval, and then quickly hauled to the surface in an oblique–horizontal–oblique or oblique-stratified-oblique tow. More complex towing strategies require a serial sampler attached to the cod-end of the net or the ability to open or close the mouth opening of the net itself.

Single nets or a net pair with a closing mechanism or both an opening and closing mechanism can be deployed to sample sub-surface strata vertically upward (Table I, tow type 3) or from the surface downward (Table I, tow types 2, 4). With the opening–closing system, tows taken underway with a single net or net pair can be hauled horizontally or in a stratified-oblique manner (Table I, tow types 12, 13). With more than one single net or net pair attached to the towing wire, several different strata can be sampled simultaneously, either obliquely over some depth interval or horizontally at a particular depth (Table I, tow types 14, 15).

With a multiple net system, additional deployment strategies are possible. In addition to vertical and oblique-stratified tows (Table I, tow types 16, 17), horizontal, oblique–horizontal and stratified-oblique–horizontal towyos (Table I, tow types 18–20), or an oblique-stepped horizontal tow (Table I, tow type 21) can be made. It is also possible for a discontinuous horizontal or stepped-horizontal tow to be made (Table I, tow types 22, 23), although these are not typical modes of deployment.

Single-net systems with multiple cod-ends such as ARIES and the Longhurst-Hardy Plankton Recorder (LHPR) (Wiebe and Benfield, 2003, Plate 27) can use the same deployment strategies as multiple net systems towed from a moving platform. Instead of multiple nets being opened and closed, there are multiple cod-ends being used sequentially or a mechanism at the cod-end that steps plankton gauze in timed intervals to collect the plankton (Table I, tow types 17–23). The continuous plankton recorder (CPR) is a special case of a serial plankton sampler usually towed horizontally (Table I, tow type 18), but without a net in front.

Finally, epibenthic plankton tows made just above the sea floor are usually horizontal tows (Table I, tow type 22). Most of these samplers have opening–closing capabilities to avoid collecting animals in the rest of the water column.

The gear deployment descriptions provided herein for nets can be generalized for use with other kinds of collecting gear, such as CTDs, towed bodies, VPRs, ROVs, AUVs, Gliders etc. Establishment of standard vocabularies and ontologies enhances the utility and interoperability of data repositories across the oceanographic community. Widespread and accurate use of these vocabularies will make it much easier for individual investigators and multi-disciplinary collaborators to exchange, share, and reuse data.

ACKNOWLEDGEMENT

The authors thank the reviewers for helpful comments.

FUNDING

This is a contribution from the Biological and Chemical Oceanography Data Management office (BCO-DMO) that is funded by the National Science Foundation Grant (#OCE-1031253).

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