Marine: Secchi disk monitoring of water clarity

Version 1.0

This specification was prepared by Kate Schimanski in 2016.

Contents

Department of Conservation
Te Papa Atawhai

Synopsis

This section is a brief summary of the application, most common approaches, key considerations and requirements associated with this methodology. For full details of how to perform Secchi depth surveys, please refer to 'Full details of technique and best practice'.

Declining water quality in many coastal ecosystems around the world is a major environmental concern. Activities such as coastal urbanisation and the removal of catchment modification can increase the supply of land-derived sediments and nutrients to marine environments (delivered through waterways, runoff and landslides) resulting in an increase in suspended sediment and a decrease in the water clarity of coastal marine environments.

Suspended sediment is defined as living (e.g. plankton) and non-living organic material (e.g. sand, silt, clay) within the water column. High levels of suspended sediment in the marine environment can decrease light penetration, reducing macroalgal growth and primary productivity, degrade visual clarity disrupting the behaviour of visual predators, affect public recreational use, and provide a medium for pollutant attachment. If suspended sediment settles, it has the potential to clog respiratory surfaces and filter-feeding apparatus, and smother benthic organisms. Increased sedimentation has been linked to reduced species diversity and a change in species assemblages (Carballo 2006). In New Zealand, sedimentation has been shown to negatively affect a range of organisms, including crustaceans (Steger & Gardner 2007), bivalves (Ellis et al. 2002) and seaweeds (Geange et al. 2014). Estuaries often have higher suspended sediments compared to marine environments due to tidal currents that prevent sediments from settling, the input of rivers, and the presence of dense populations of phytoplankton. Suspended sediment can be used as a health indicator in coastal ecosystems, and is consequently an important covariate.

Suspended sediment can be monitored in a number of ways, including electronic turbidity meters or sensors and acoustic Doppler meter backscatter. However, this methodology focuses on Secchi depth, a measurement of water clarity that is simple, cheap and directly related to the quantity of suspended sediments in the water column (Dodd & Vopel 2010; Auckland City Council 2013). Secchi depth is measured using a Secchi disk, a classic ecological tool and the first instrument used to provide a measure of *in situ* water clarity. A Secchi disk is a black and white circular disk normally 20 cm in diameter (larger disks are used when working from high-sided ships). The disk is negatively buoyant, enabling it to sink vertically when deployed. A commercial transect tape is attached and the Secchi disk is lowered into the water until the disk can no longer be seen. The depth between the water surface and the disk is recorded as the Secchi depth. A viewing box may also be used if available, which removes the effects of water glare at the water surface, increasing precision of the observation (see Smith 2001).

Secchi depth is commonly recorded in many marine field studies because suspended sediment is an important environmental covariate. Secchi depth can be measured in any body of water, including rivers and lakes. Due to its simplicity and the durability of the equipment involved, this methodology has proven amenable to application by school students, community groups or citizen scientists wanting to undertake marine surveys.

Examples of the type of applications that Secchi depth surveys can be applied to include:

- Determining changes in water clarity throughout the year
- Determining if water clarity differs around urban areas relative to non-urbanised areas
- Monitoring turbidity at dredge sites
- Monitoring stream and river inputs into the marine environment
- Collection of covariate data for biological surveys

Key considerations to take into account when considering applying Secchi disk methodologies include:

- The weather conditions and sea state
- Orientation to the sun
- Any covariate information to be recorded concurrently (e.g. sea surface temperature, salinity)
- Skill level required of personnel
- Equipment and other resources required
- Number and placement of replicates
- Temporal replication

Assumptions

- Observer effort, method and skills are similar across sites, locations and/or sampling occasions.
- Secchi depths sampled represent the variability (temporal and spatial) of the area of interest (if no additional information is to be collected as covariates).

Advantages

- Non-destructive.
- Simple, robust equipment that requires minimal maintenance (rinsing in freshwater and drying after use).
- Data do not require any conversions or calculations.
- Minimal training required as methodology is simple and accessible to a range of people, including citizen scientists.
- If the study is correctly designed, random sampling of an area is possible.
- Can be used in long-term monitoring.
- Sampling is easily repeatable over time.

- The method is amenable to the collection of covariate data regarding the physical environment (e.g. sea surface temperature, salinity).
- Reasonably quick and cost effective to gather data from a high number of sampling units.
- Can be utilised for a wide range of habitat types.

Disadvantages

- Only provides data for the area that has been sampled, hence it is very much dependant on site selection relative to the spatial heterogeneity of the habitat.
- Similarly, only provides data at one point in time and is dependent on sampling date. Water clarity may be affected by currents (including tidal), river discharge, storm events and terrestrial activity (e.g. landslides, excavation, discharge) and consequently sampling designs need to consider temporal variation in readings.
- Can be slower than using electronic equipment, such as a nephelometer, to measure suspended sediments.
- There may be operator bias (depending on eyesight accuracy).
- Measurements may be affected by environmental variables such as sea state (calm or chopping), surface glare, cloud cover, and side of boat measured on (shaded or sun).
- Precision of data heavily relies on protocols being closely followed for reasons described above.
- Should not be used to describe light extinction coefficients or the thickness of the euphotic zone.

Suitability for inventory

- Due to the temporal variability in suspended sediments, this technique, which only samples at one point of time, is not suitable for an inventory survey.

Suitability for monitoring

- Secchi depth sampling is well-suited to monitoring suspended sediments due to the ability to replicate the same method over time and space with a high level of consistency, and often quickly.
- Secchi depth is commonly recorded as a covariate in large monitoring programmes or as a supplementary method in sedimentation monitoring (e.g. Dodd & Vopel 2010).
- Careful consideration must be given to other factors (e.g. storm events) when selecting sampling periods, and these should also be documented.

Skills

Secchi disk monitoring requires a relatively low level of expertise.

Pre-survey:

- Survey design skills for determining the study objective, number of replicates, stratification (if any) and placement of replicates, and what covariates are to be recorded
- GIS knowledge for the planning of field locations and sites
- Transfer of site coordinates to portable GPS

In the field:

- Thorough understanding of sampling protocol
- The skills to record and securely manage data
- Use of portable GPS

Data analysis:

- Familiarity with basic statistics
- Familiarity with statistical package (R recommended)

Resources

- Sunscreen, hat, insect repellent and plenty of snacks and water.
- Wet weather gear and warm items of clothing as weather can change quickly.
- General field equipment, including pencils, slates, waterproof paper, datasheets.
- Data recording sheets, printed on waterproof paper. Figure 1 shows a generic Secchi disk field data sheet; however, this may need to be adapted depending on the particular survey objectives and design.
- GPS unit for site location.
- Equipment to measure any relevant covariates, such as sea surface temperature.
- Sample container and waterproof ID label. If the Secchi depth is less than expected and a phytoplankton bloom is suspected, a water sample container and ID label would allow a sample to be collected for identification and informing authorities if necessary.
- A survey vessel and associated personnel (with necessary safety planning completed), if sampling is to be boat-based.
- Personnel time for the adequate completion of all stages of the project, including planning, field work, data management and analysis, and write-up of the survey and results.

SECCHI DISK SURVEY Department of Conservation *Te Papa Atawhai* **DOCCM-2800647**

Date:	Survey:	Observer:
Vessel:	Location:	Recorder:
Skipper:	Weather:	Secchi disk size:
Survey leader:		Viewing box used?: Y N

UID 1,2,...	Site name	Lat/long	Time	Tide	Depth (m)	Secchi depth readings (m)				Transect		Other/notes
						Disapp 1	Reapp 1	Disapp 2	Reapp 2	#	Dist. along	

Figure 1. Generic Secchi disk field data sheet datasheet adapted from Dodd & Vopel (2010).

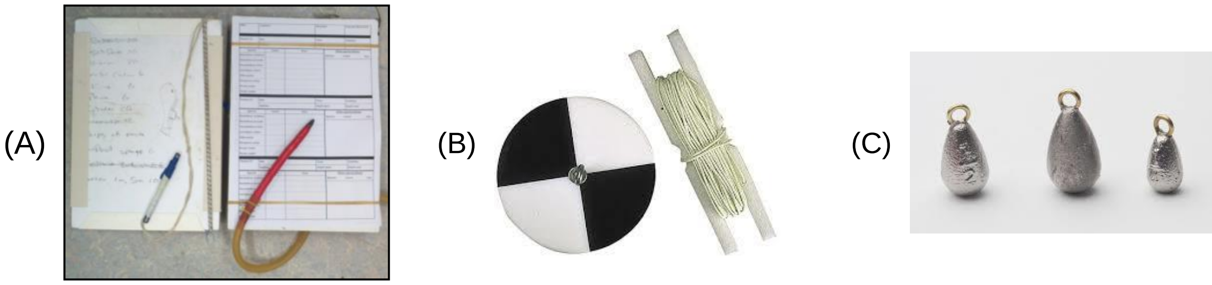

Figure 2. A selection of resources required to measure Secchi depth: (A) datasheets (on waterproof paper), clipboard and pencil; (B) Secchi disk and measuring line; and (C) weights, needed when sampling in high-flow areas.

Minimum attributes

Consistent measurement and recording of the following attributes is critical for the implementation of the method. Depending on the research question(s), other attributes may be required.

DOC staff must complete a ‘Standard inventory and monitoring project plan’ (doccm-146272).[1]

[1] http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-standard-inventory-and-monitoring-project-plan.doc

Survey metadata

- Survey name
- Survey objectives
- Survey period (dates)
- Site name and coordinates
- Observer and recorder's names
- Vessel name
- Date and time
- Tide
- Weather
- Size of Secchi disk used
- How sampling sites were spatially arranged (e.g. random, random within stratified areas, fixed)

Secchi depth data

- Location of Secchi disk deployment within the site
- Secchi (replicate) number
- Water depth
- Secchi depth (a 'disappearing' reading and a 'reappearing' reading, as described in 'Full details of technique and best practice')

Optional attributes

- Transect number (if Secchi depths are distributed along a transect) and distance along the transect
- Covariates associated with the Secchi depth (e.g. temperature, sea state, cloud cover, distance to coastline), or any other covariate data of interest, such as a broader habitat characterisation
- Any additional notes or comments that may be useful for future surveys or for interpretation of the results, e.g. if a site was too shallow to take a Secchi depth measure
- Details of any physical samples collected, such as an opportunistic plankton or water sample

Data storage

DOC is currently developing a national database to hold and provide access to data collected from marine reserve monitoring in New Zealand. The aims of the database are to:

- Support consistent standards in national marine reserve monitoring programmes for marine environmental quality
- Coordinate and optimise marine reserve monitoring in New Zealand
- Provide a high quality monitoring dataset for New Zealand's marine reserves

Once operational, this methodology will be updated with a description of how to lodge data within the national database. In the interim, data should be recorded within the spreadsheets associated with this methodology. It is essential that all raw data sheets are completed, digitised and backed up on external hard drives. Raw data and associated metadata should be entered into databases/spreadsheets in a standardised format. This should include metadata stored in a separate sheet, and a sheet containing sampling data collected during the monitoring programme stored in one 'brick' of data that can be continually updated as more surveys in that monitoring programme are carried out.

For internal DOC monitoring, information pertaining to each survey within a marine reserve and resultant data/reports should be entered into the Marine Protected Area Monitoring and Research (MPAMAR) datasheet ('MPAMAR metadata—National'—doccm-1163829) so there is an easily accessible account of the survey.

Analysis, interpretation and reporting

Seek advice from a statistician or suitably experienced person prior to undertaking any analysis. Ideally, statistical advice should be sought prior to any data collection to ensure that the design of the data collection is robust and suitable for answering the question at hand. For quality control the data should be checked for unlikely abundances of organisms, and errors in data entry.

Data analysis

The common method for summarising and presenting Secchi depth data is to calculate mean Secchi depth and corresponding statistical variance. Secchi depth data from each replicate are summed and an average calculated for that site. Statistical variance provides a measure of how the data are distributed around the mean. If Secchi depths are taken regularly through time, a time series of mean Secchi depth for a site or location could also be presented.

Interpretation

Interpretation of results should be performed with the assistance of a statistician as well as consideration of the major driving forces operating within the system. At this stage, it should be determined whether the objectives of the original data collection have been achieved and whether the data are sufficient to answer those questions outlined prior to the initial surveys.

Reporting

It is likely that Secchi depth data will be part of a larger monitoring programme. Reporting will largely be governed by the duration of the monitoring and data collection. If data collection is ongoing, regular reports should be submitted at 3–5-year intervals, whereas for short-term (< 2 years in duration) data collection, reports should be submitted within a year of the final data collection.

Case study A

Case study A: Proposal for monitoring sedimentation in Te Whanganui-A-Hei Marine Reserve (Dodd & Vopel 2010)

Synopsis

An increase of fine-grained sediment particles (which can affect the health of marine ecosystems) was identified within Te Whanganui-A-Hei (Hahei) Marine Reserve by DOC over several biological monitoring programmes since the formation of the reserve in 1993. Due to a lack of quantitative data on sedimentation in the reserve, DOC, in collaboration with the School of Applied Sciences at Auckland University, carried out a pilot study for establishing long-term monitoring of suspended sediments in the reserve. Although turbidity (using a nephelometer) and settling particulars (using sediment traps) were also measured in the proposal, this case study focuses on trialling the measurement of Secchi depth. Fifteen sites along each of two 3-kilometre transect lines were sampled. These transects covered a range of habitats both inside and outside the reserve. Secchi depth differed from one end of the reserve to the other.

Objective

- To assess the suitability of methods for monitoring suspended particles and sedimentation for informing the establishment of a long-term monitoring programme.

Sampling design and methods

- Fifteen sites located along each of two 3-kilometre transect lines were sampled.
- One transect was located in the eastern region of Te Whanganui-A-Hei Marine Reserve. The second transect line was located in the western region of the reserve. Each transect began inside the reserve close to the land and ran perpendicular to the shore line. The 15 sites along each transect line were evenly spaced with 200 m separation from one another (Figure 3).
- The transect lines were positioned along a gradient of water turbidity: high turbidity in close proximity to Whitianga Estuary, lower turbidity in the eastern region of the reserve. The transect lines also crossed habitat types from shallow waters inside the reserve to deep water outside the reserve. The design allowed adequate high-resolution data to be collected in a single day. Secchi depths were recorded on 2 June 2010.

- The disk observer had 'Normal' eyesight and was not wearing sunglasses.
- For consistency, the same observer recorded all the measurements at each site throughout the monitoring period.
- Measurements were taken from the sunny side of the boat when possible.
- The Secchi disk was securely attached to a measure line.
- The Secchi disk was slowly lowered into the water.
- A viewer box was used with the Secchi disk (see description in 'Resources').
- At each site, two Secchi depth readings were recorded. The observer noted the depth (i.e. distance from the viewer box to the face of the Secchi disk) at which the disk disappeared from view on deployment. The observer then noted the depth at which the disk then reappeared when pulling in the Secchi disk.
- The measurements were repeated at each site.
- The resulting four measurements for each site (two measurements for Secchi disk disappearance, and two measurements for Secchi disk reappearance) were used to calculate mean Secchi depth for each site (Figure 4).

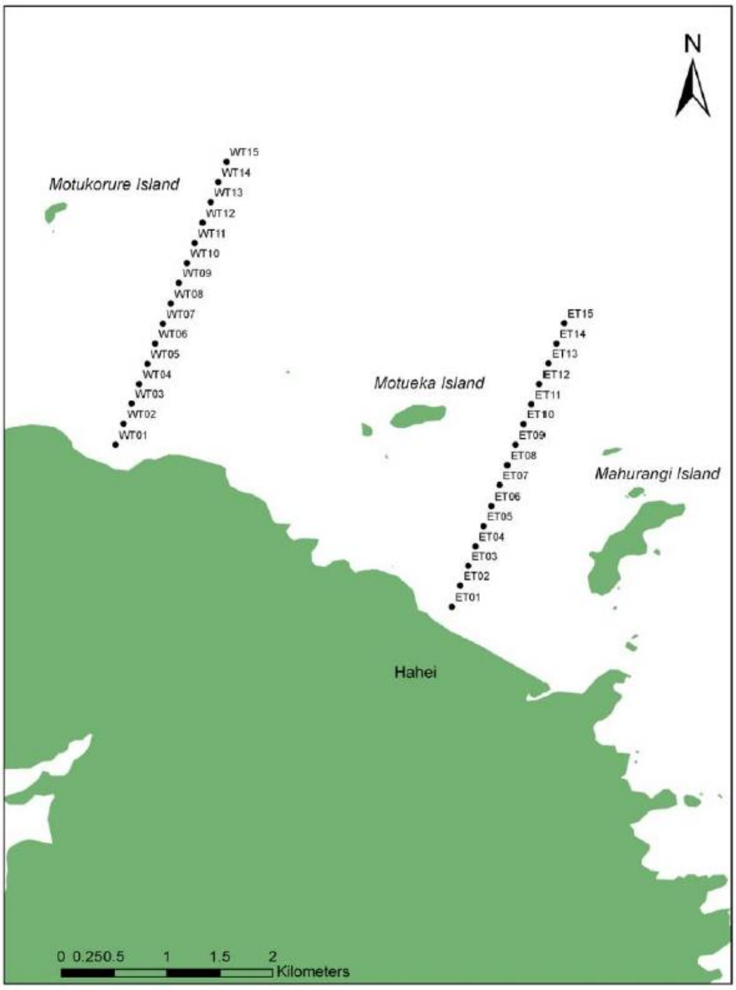

Figure 3. The location of two transects in Te Whanganui-A-Hei Marine Reserve, Whitianga. Each circle marks the location of one sampling site. There are 15 sites along each of the western (WT01–WT15) and eastern (ET01–ET15) transect lines. Taken from Dodd & Vopel (2010).

Results

- Secchi depths along the eastern transect line remained fairly constant between 3–4 m. The western transect line began with a Secchi depth similar to that of the eastern transect line. However, after about 0.8 km along the transect line, the Secchi depth was reduced to approximately 1–2 m (Figure 4).
- Secchi depth results were consistent with seawater turbidity made with a multiparameter sonde.

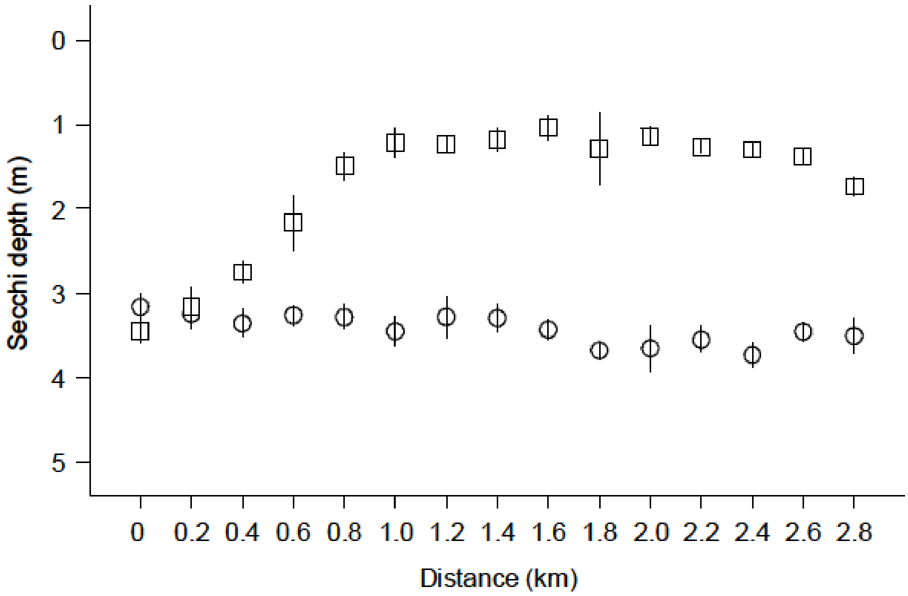

Figure 4. Mean Secchi depth (*n* = 4) at sites along two transect lines. The square symbols indicate sampling sites along the western transect line and the circle symbols indicate sampling sites along the eastern transect line. Distance starts at the first sampling site closest to the shore. Error bars indicate one standard deviation. Taken from Dodd & Vopel (2010).

Limitations and points to consider

- It is essential that a protocol for collecting the Secchi depth data is established at the beginning of a monitoring programme and closely followed through the duration of the programme to improve precision.
- It is essential the same observer is used throughout to improve precision.
- The Secchi depth is a simple measure of water clarity, but does not give information about vertical distribution of particles, which can be recorded using other devices.
- This methodology illustrates how Secchi depth sampling can be used efficiently to collect data for suspended sediments and water clarity.

References for case study A

Dodd, S.; Vopel, K. 2010: Proposal for monitoring sedimentation in the Te Whanganui-a-Hei Marine Reserve. Report prepared for the Department of Conservation by Auckland University of Technology. 39 p.

Case study B

Case study B: Long-term trends in water clarity revealed by Secchi-disk measurements in lower Narragansett Bay (Borkman & Smayda 1998)

Synopsis

Secchi depth observations (*n* = 1076) were made weekly in lower Narragansett Bay, Rhode Island, USA, over a period of 25 years (1972–1996). This time series was used to describe the variability of the light-attenuating properties, to quantify long-term trends, and to identify possible causative mechanisms. A significant 25% increase in Secchi depth was recorded over the study period with the greatest increase occurring between 1984 and 1994. The increase in Secchi depth coincided with a 75% decrease in total suspended solids introduced to the Bay via wastewater treatment plants, and is similar to other coastal waters that have also experienced reductions in anthropogenic total suspended solid loading. In addition to the long-term trend, there was a strong seasonal trend in water clarity.

Objective

- To record light attenuating properties in Narragansett Bay.
- To quantify long-term (25-year) trends in light-attenuating properties.
- To identify possible causative mechanisms behind any trends.

Sampling design and methods

- Samples were taken at the same single location in an unpolluted passage in the Bay (Figure 5).
- Measurements were taken weekly from January 1972 to December 1996.
- A white 0.3 m Secchi disk was lowered into the water until it was no longer visible.
- Sampling occurred within 4 hours of noon to minimise the effect of sun angle on readings.
- Sampling was taken from the sun-facing side of the boat to minimise the effect of reflectance.
- Sampling was taken from the same location on the boat deck to minimise the effect of observer height above sea level.

- Although tidal cycle may influence Secchi readings, this study found that water clarity only varied by 1% over the tidal cycle at the sampling location, and the effect of tidal phase on water clarity appeared to be small.
- Other covariates measured were temperature, salinity, Chlorophyll *a,* dissolved inorganic nutrients, zooplankton dry weight, phytoplankton abundance and community composition, windspeed and ambient solar radiation, precipitation and river runoff (note that some of these data were collected by other laboratories).

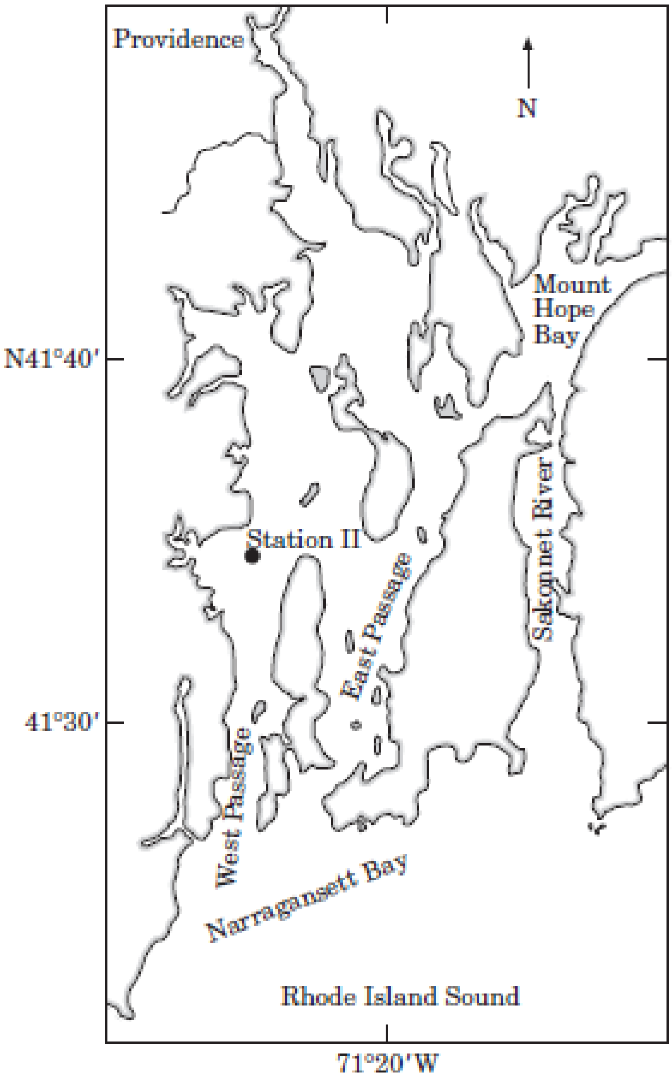

Figure 5. Location of long-term sampling Station II in the lower west passage of Narragansett Bay, Rhode Island, USA. Taken from Borkman & Smayda (1998).

Results

- Secchi depth ranged over 6.5 m. It reached a minimum of 0.5 m during a summer plankton bloom in 1985 and reached a maximum of 7 m in spring 1992. The mean value between 1972 and 1996 was 2.75 m (± 0.95 m standard deviation). Both long-term and seasonal trends were detected (Figure 6).

- Secchi depth increased over the sampling period at a linearised rate of 0.05 m/year^{-1}. This increase can be divided up into three phases: from 1972 to 1983 there was no significant trend, between 1984 and 1994 there was a significant increase in Secchi depth, and the depth remained high between 1995 and 1996 (Figure 7).
- Secchi depth was influenced by seasons. Increases in Secchi depths were strongest in winter and autumn and weakest or not significant in spring and summer (Figure 8).

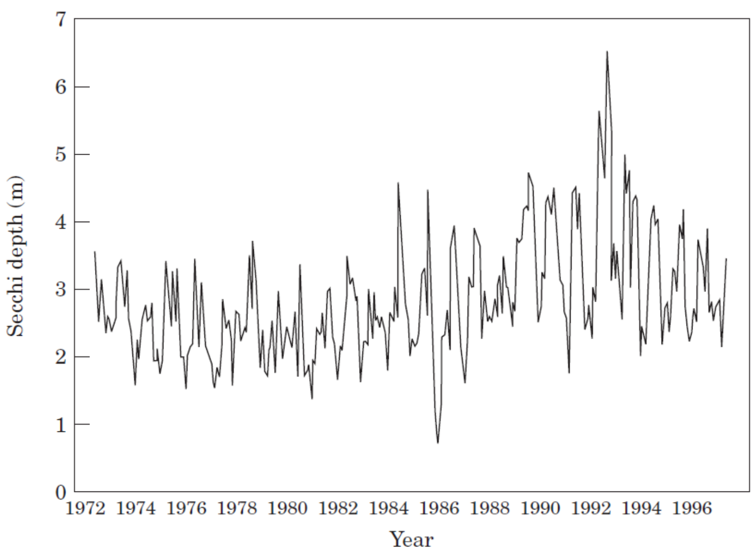

Figure 6. Mean monthly Secchi depth at Station II, 1972–1996. Each data point is the mean of all observations for each month. Taken from Borkman & Smayda (1998).

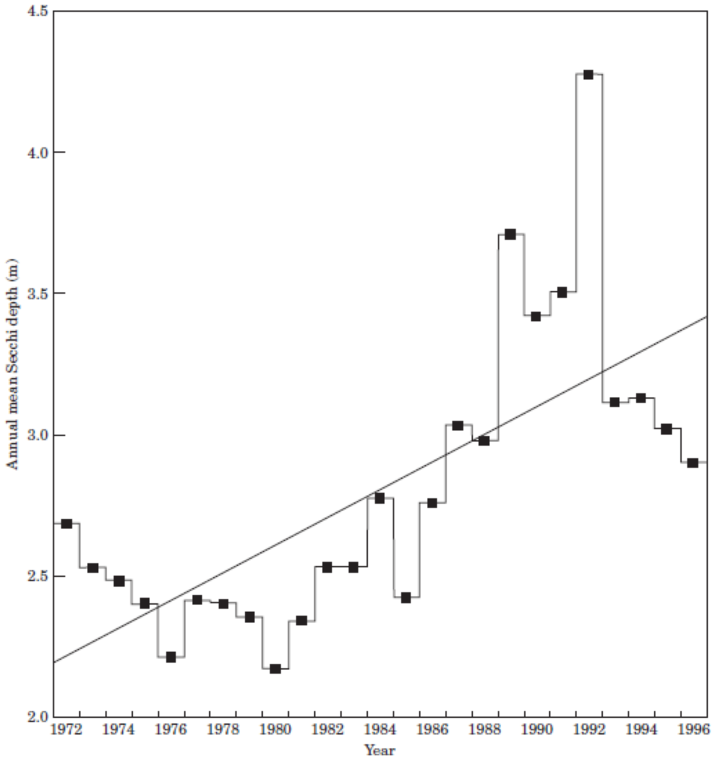

Figure 7. Mean annual Secchi depth at Station II, 1972–1996. Each data point is the mean of all observations in each year. Line represents linear regression ($y = 0.05x + 2.16$, $r^2 = 0.50$). Taken from Borkman & Smayda (1998).

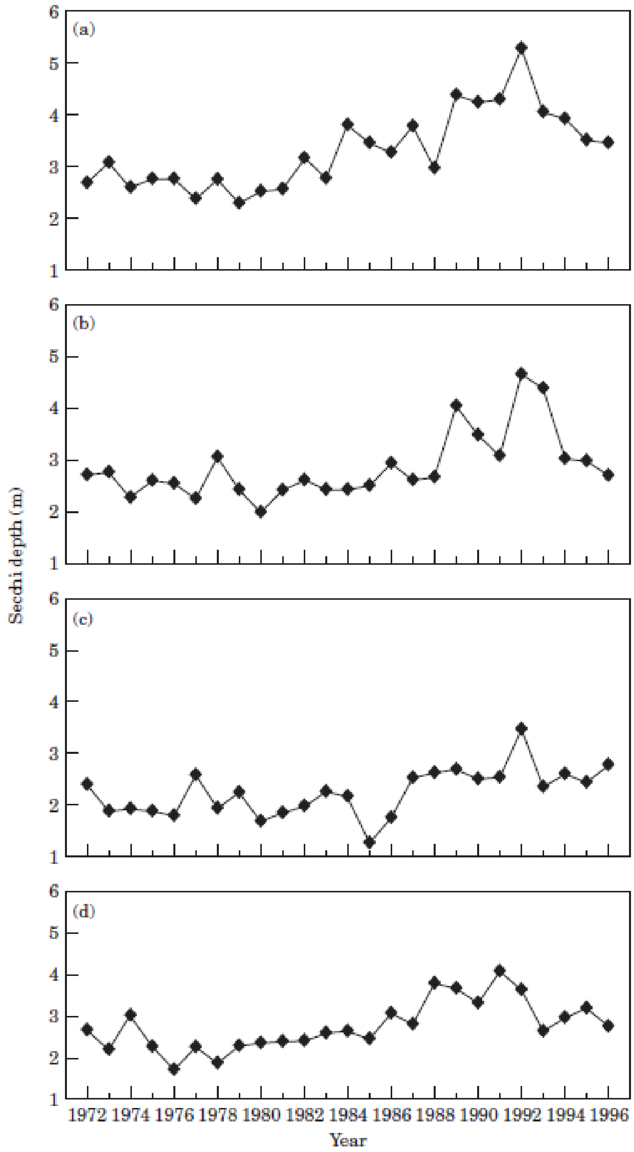

Figure 8. Mean Secchi depth at Station II by quarter, 1972–1996. Each data point is the mean of all observations in that quarter in each year. (a) Winter (Jan–Mar); (b) Spring (Apr–Jun); (c) Summer (Jul–Sep); (d) Autumn (Oct–Dec). Taken from Borkman & Smayda (1998).

Limitations and points to consider

- Consider outfall or sewage discharge in the area of sampling.
- Samples should be taken at the same location when making temporal comparisons or examining trends.
- Each sampling event should occur at a similar time to minimise the effect of sun angle on readings.
- Sampling should be taken from the sun-facing side of the boat to minimise the effect of reflectance.
- Sampling should be done from the same location on the boat deck to minimise the effect of observer height above sea level.
- The influence of tidal cycle will depend on the sampling location and should be considered when designing the study – it could be significant or minor.

- Other covariates should be measured.
- This methodology illustrates how Secchi depth sampling can be used efficiently to collect data for suspended sediments and water clarity.

References for case study A

Borkman, D.G.; Smayda, T.J. 1998: Long-term trends in water clarity revealed by Secchi-disk measurements in lower Narragansett Bay. *ICES Journal of Marine Science: Journal du Conseil 55*: 668–679.

Full details of technique and best practice

The description of Secchi depth sampling below provides generic information for applying this methodology. There is no standard protocol for measuring Secchi depth; however, this protocol is based on that used by Dodd & Vopel (2010). If more detail is required on a specific application (e.g. sampling in a high-flow environment), please refer to relevant publications in the scientific literature or contact DOC's Marine Ecosystems Team for advice. The description below is structured around the key steps that should be followed when planning and carrying out a survey using Secchi depth sampling methodology.

Survey design

Monitoring preparation includes developing a robust survey design, including prior consultation with experts/statisticians, to ensure the design meets the requirements to answer the research question. The following aspects need to be incorporated into a robust survey design:

- Identification of monitoring objectives.
- Statement of clear outcomes of the surveys and how they relate to the original monitoring objectives.
- Determine the number of sites to be surveyed within the survey location, and where they are to be situated.
- Determine the number of Secchi measurements to be sampled at each site and their spatial arrangement within the site.
- Determine a survey schedule to ensure that data are collected as required over the lifetime of the study.
- Determine the appropriate time of day to take Secchi measurements, e.g. on the same tidal cycle if working in an estuary.

Sampling procedure

Following the determination of a clear and robust survey design, the following steps outline a typical process for conducting a transect survey.

After determining a clear and robust survey design:

- Ensure all personnel involved in sampling are clear about the protocol for the particular survey they are conducting. This should include any rules relating to environmental variables such as sea state (calm or chopping), surface glare, cloud cover, side of boat measured on (shaded or sun) and observer bias.
- Navigate to the site where sampling is to begin, using either pre-determined GPS coordinates, previous site descriptions, or permanent markers.
- Record survey metadata and data for the survey using the 'Secchi depth: field data sheet' (doccm-2800647)[2] (Figure 1; see Table 1 for field explanations).
- Deploy the Secchi disk. The following protocol is a modification of that presented in Dodd & Vopel (2010):
  - The observer must have 'Normal' eyesight and not be wearing sunglasses.
  - For consistency, the same observer must record all the measurements at each site throughout the monitoring period.
  - Measurements should be taken from the sunny side of the boat when possible.
  - Ensure that the Secchi disk is securely attached to the measuring line, and accurately attached at the '0' mark.
  - Lean over the side of the boat and slowly lower the Secchi disk into the water (Figure 9). If there is current, a weight can be attached below the Secchi disk.
  - The observer notes the depth (as indicated by the reading of the measuring line at the water surface) the disk disappears (i.e. distance from the Secchi disk to the water surface), and a recorder documents this data on the data sheet as a 'disappearing' reading.
  - The observer continues to lower the Secchi disk, and then raises it again, recording the depth at which the disk then reappears as a 'reappearing' reading. The depth should be recorded to the nearest 5 cm.
  - The above is then repeated, giving two 'disappearing' and two 'reappearing' measurements at each site.

Table 1. Minimum attributes to be recorded for Secchi depth sampling.

Database field	Description	Value
Location	General locality where the sampling occurred (e.g. Ulva Island).	Short text
Survey	A name for this survey. Allows to differentiate surveys achieved at different dates at similar location (e.g. Poor Knights Feb 2015).	Short text
Survey leader	Name (first name + surname) of the person in charge of this survey.	Short text

[2] http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-secchi-depth-field-data-sheet.pdf

Site name	Site within *Location* where the sampling occurred.	Short text
Latitude	Decimal degree latitude for the location of the Secchi disk deployment (WGS84) (e.g. latitude for Wellington Conservation House is −41.289904).	Number with up to 6 digits after decimal. Values are between −90 to 90, but typically negative for New Zealand.
Longitude	Decimal degree longitude for the location of the Secchi disk deployment (WGS84) (e.g. longitude for Wellington Conservation House is 174.775043).	Number with up to 6 digits after decimal. Values are between 0 and 360.
Secchi disk size	Diameter of the Secchi disk used (cm).	Integer
Viewing box used	Whether a viewing box was used to aid observations.	Yes or No
Vessel	Vessel used to deploy the diver, if appropriate.	Unlimited text
Observer	Name of the person who made the Secchi depth reading.	Unlimited text
Recorder	Name of the person who recorded the Secchi depth reading.	Unlimited text
Date	Date of sampling.	Date (dd/mm/yyyy)
Tide	Simplified tidal level at the time of sampling.	One of the four values: • Low • Medium • High • Undetermined
Weather	Description of the atmospheric conditions (wind, sea state, swell, etc.).	Unlimited text
Time	Time at which the quadrat was sampled.	Time in 24 h format (hh:mm)
UID	A unique identifier for each Secchi depth deployment during this survey.	Integer
Water depth	Depth of water where the Secchi depth reading was made (in metres).	Integer
Secchi depth disappearing1	Depth at which the Secchi disk disappears from the observer’s sight (in metres)—first reading.	Integer
Secchi depth reappearing1	Depth at which the Secchi disk reappears to the observer’s sight (in metres)—first reading.	Integer
Secchi depth disappearing2	Depth at which the Secchi disk disappears from the observer’s sight (in metres)—second reading.	Integer
Secchi depth reappearing2	Depth at which the Secchi disk reappears to the observer’s sight (in metres)—second reading.	Integer

Figure 9.The Secchi disk and measuring line slowly lowered over the side of the boat.

Processing of samples

Direct observation of the Secchi disk generally will not require the collection of any samples unless it is a component of a wider monitoring programme (exceptions to this may be when there is a phytoplankton bloom and samples are desired for identification, or analysis of suspended matter in the water column is required).

Timing

Consideration of timing of the surveying activity should include:

- Tidal cycle, weather (in particular, any proceeding storm or rain events), seasonal effect or lunar characteristics and how this may affect surveying (including whether previous surveys have occurred at a certain time of year/day etc.)
- What are deemed 'safe' hours of operation for the surveying activity (e.g. for allowing enough time for personnel involved to return safely home/back to base within daylight hours)

Safety

Safety is paramount during any survey activity. The safety recommendations below are provided as general guidance, but it is imperative that the survey leader understands all risks associated with the activity, always uses caution, and develops a Safety Plan for the survey activity and location (DOC staff should use RiskManager, and non-Departmental staff should consult WorkSafe New Zealand's 4-step risk management[3] or their own organisation's safety plans. Safety Plans should include resources (e.g. equipment, boats, communication, support, personal protective equipment), environmental hazards or considerations (e.g. remoteness, surf zones), personnel (experience, training, physical and mental fitness), weather and mission complexity. Following a thorough safety briefing, all team members should read and then sign the Safety Plan.

3 http://www.worksafe.govt.nz/worksafe/hswa/health-safety/how-to-manage-work-risks

Specifically, it is recommended that:

- A minimum of two people make up the survey team
- All personnel should operate within the limits of their training and experience
- The magnitude and complexity of the survey are relevant for the planned duration of the survey

Quality assurance

A measure of observer accuracy or bias in Secchi disk readings will provide an assessment of the confidence that can be had in the results. This has, to an extent, been built into this protocol by taking repeat measures at each site, although within-site replication could be further increased. Additionally, an additional experienced observer could make observations of a subset of Secchi depths by way of an audit. Another key stage to apply a quality assurance measure is at the data entry stage by auditing a subset of data sheets against what has been entered in the database.

References and further reading

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Appendix A

The following Department of Conservation documents are referred to in this method:

doccm-1163829	MPAMAR metadata—National
doccm-2800647	Secchi depth: field data sheet
doccm-146272	Standard inventory and monitoring project plan