Document title	Progress in developing spring bloom chlorophyll-*a* indicator
Code	5-5
Category	CMNT
Agenda Item	5 – Further development of HELCOM eutrophication assessment methodology
Submission date	5.2.2015
Submitted by	Finland, SYKE
Reference	EUTRO-OPER 1-2014

Background

One of the tasks of EUTRO-OPER was to complement the core set of indicators through developing new indicators. EUTRO-OPER 1-2015 agreed to develop an indicator on annual chlorophyll–a spring bloom indicator that describes the intensity of spring bloom period. The first version of the spring bloom indicator was developed in MARMONI-project. Work done under EUTRO-OPER will examine the applicability of the indicator to HELCOM assessment areas.

This work is input to subtask 3b.i in the EUTRO-OPER roadmap.

Stage of the work:

The spring bloom method has been applied for pilot years 2006-2009 for HELCOM assessment areas SEA-7 – SEA -17. Other years are under calculation. The final indicator status will be calculated for 2007-2011.

GES will be determined quantitatively using the target approach. For the time being, trend based targets are used, for illustration purposes.

The confidence of the presented spring bloom indicator estimate will be defined at later stage.

Action required

The Meeting is invited to note the development of the indicator and discuss the work.

FRONT PAGE

[Status map will be given after the indicator is defined for the assessment period 2007 - 2011.]

Key message

The status of spring bloom indicator for HELCOM assessment areas SEA-7 – SEA-17 will be defined during year 2015. The method is under development, but initial results are given in this document. The method works well for regions with clear and intensive spring bloom such as assessment areas Gulf of Riga and Gulf of Finland. For the current version of the indicator the status shows increasing trend in the Gulf of Riga and no trend for the Gulf of Finland.

The confidence of the spring bloom status estimate is high due to the large amount of EO data. However, for many assessment areas, its accuracy cannot be verified against monitoring station data due to the lack of vernal monitoring data.

Relevance of indicator

Spring bloom indicator is used as a proxy of phytoplankton total biomass during the spring period. Phytoplankton increases along with increased eutrophication, as a result of increased nutrient concentrations. The indicator also reflects changes in the phytoplankton annual succession as a result of changes in food web, hydrography and climate change affect the indicator.

Policy relevance of the core indicator

	Primary importance	Secondary importance
BSAP segment and objective	Eutrophication: natural level of algal blooms	Biodiversity: thriving and balanced communities of plants and animals
MSFD descriptor and criteria	5.2	1.6
WFD, quality element	QE1	

Authors

Attila Jenni[1], Junttila Sofia[1], Fleming-Lehtinen Vivi[2], Heidi Hällfors[1]

1 Finnish Environment Institute (SYKE), P O Box 140, FI-00251, Helsinki, Finland

2 Secretariat of the Helsinki Commission, HELCOM

Refer to this indicator

[to be filled later]

INDICATOR CONCEPT

Policy relevance

Eutrophication is one of the four thematic segments of the HELCOM Baltic Sea Action Plan (BSAP) with the strategic goal of having a Baltic Sea unaffected by eutrophication (HELCOM 2007). Eutrophication is defined in the BSAP as a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae which leads to imbalanced functioning of the system. The goal for eutrophication is broken down into five ecological objectives, of which one is "natural levels of algal blooms". Increase in phytoplankton can be assessed using chlorophyll-a depth as a proxy. The spring bloom indicator integrates the spring bloom period chl-a concentrations to index values that are comparable for different years.

The EU Marine Strategy Framework Directive (Anonymous 2008) requires that "human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters" (Descriptor 5). "Chlorophyll concentration in the water column" is listed as an indicator for assessing the criterion for "direct effects of nutrient enrichment" (5.2).

The EU Water Framework Directive (Anonymous 2000) requires good ecological status in the European coastal waters. Good ecological status is defined in Annex V of the Water Framework Proposal, in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics, including chlorophyll-*a*. For the time being, spring bloom period is not taken into account in WFD reporting, but the use of EO data enables this in the future.

Role of spring bloom in the ecosystem

The indicator estimates the annual total biomass of the phytoplankton spring bloom. The spring is a period of extensive and rapid phytoplankton growth, during which the main part of the annual phytoplankton production occurs. Phytoplankton quantity is a direct proxy of eutrophication, through the increase of nutrient concentration. The nutrient load is in some areas added by internal nutrient loading from the bottom, accelerated by oxygen depletion. Phytoplankton increase in turn adds to the oxygen depletion, when sedimented to the bottom, causing a vicious circle of eutrophication. Biotic and abiotic changes, such as climate change or changes in herbivory, also affect the phytoplankton quantity.

Good environmental status

At present, spring bloom indicator uses trend based approach. The target is decreasing or no trend for all assessment areas. Good environmental status for spring bloom is currently being defined based on modelling approach.

Table 1. Target values for the spring bloom indicator are to be defined during 2015.

HELCOM_ID	**Basin**	**Target (µg l–1)**
SEA-001	Kattegat	NA (decreasing / no trend)
SEA-002	Great Belt	NA (decreasing / no trend)
SEA-003	The Sound	NA (decreasing / no trend)
SEA-004	Kiel Bay	NA (decreasing / no trend)
SEA-005	Bay of Mecklenburg	NA (decreasing / no trend)
SEA-006	Arkona Sea	NA (decreasing / no trend)
SEA-007	Bornholm Sea	Under progress (decreasing / no trend)
SEA-008	Gdansk Basin	Under progress(decreasing / no trend)

SEA-009	Eastern Gotland Basin	Under progress(decreasing / no trend)
SEA-010	Western Gotland Basin	Under progress(decreasing / no trend)
SEA-011	Gulf of Riga	Under progress(decreasing / no trend)
SEA-012	Northern Baltic Proper	Under progress(decreasing / no trend)
SEA-013	Gulf of Finland	Under progress(decreasing / no trend)
SEA-014	Åland Sea	Under progress(decreasing / no trend)
SEA-015	Bothnian Sea	Under progress(decreasing / no trend)
SEA-016	The Quark	Under progress(decreasing / no trend)
SEA-017	Bothnian Bay	Under progress(decreasing / no trend)

Anthropogenic pressures linked to the indicator

The increase of chlorophyll-*a*, a proxy of phytoplankton biomass, in the water column is dependent on nutrient concentrations, and thus linked strongly to anthropogenic nutrient loads from land and air.

Assessment protocol

The assessment units for the indicator are the open Baltic Sea sub-basins SEA-7 – SEA-17 (HELCOM 2013b).

Figure 1. HELCOM assessment areas.

The indicator estimates the annual total biomass of the phytoplankton spring bloom. The spring is a period of extensive and rapid phytoplankton growth, during which the main part of the annual phytoplankton production occurs. Quantifying the bloom biomass is not easy using traditional methods, which do not react at a high spatial or temporal scale. The biomass can be estimated through combining EO and ship-of-opportunity data, in order to obtain maximum spatial and temporal coverage, and is further development of the spring bloom index developed by Fleming and Kaitala (2006). At present, EO data is utilized.

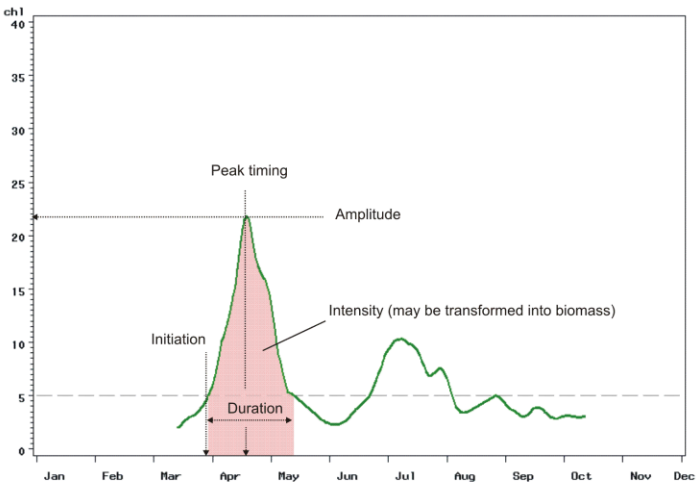

Figure 2. The properties of the spring phytoplankton bloom in the western Gulf of Finland in 2009, characterized from a time series of chlorophyll-a concentration. The intensity is defined as integral of the chl-a concentrations during the spring bloom period (Fleming and Kaitala, 2006).

The spring bloom indicator method was originally developed for MARMONI project study areas and for the coastal WFD-areas of Finland. During the last autumn, it has been developed further for HELCOM assessment areas. As spring bloom period is short, intensive and often spatially 'limited', the spring bloom tends to average out using HELCOM assessment areas. Thus, HELCOM 20km grids have been utilized to determine sub-indicator indexes. These sub-indicators are then combined to represent the whole assessment areas.

The method utilizes time series of non-cloudy EO chlorophyll-*a* concentrations observed on each HELCOM grid (see Figure 4 for example of grid division). The start and end of the spring bloom is defined based on a threshold (chlorophyll-*a* concentration above 5 µg/l). For the period between the annual start and end of the spring bloom, EO observations are complemented to daily chlorophyll-*a* concentrations by using spline interpolation method. The spring bloom index for each grid is defined as an integral of the spline. Finally, grid based sub-indicators are combined (averaged) to represent the whole assessment areas.

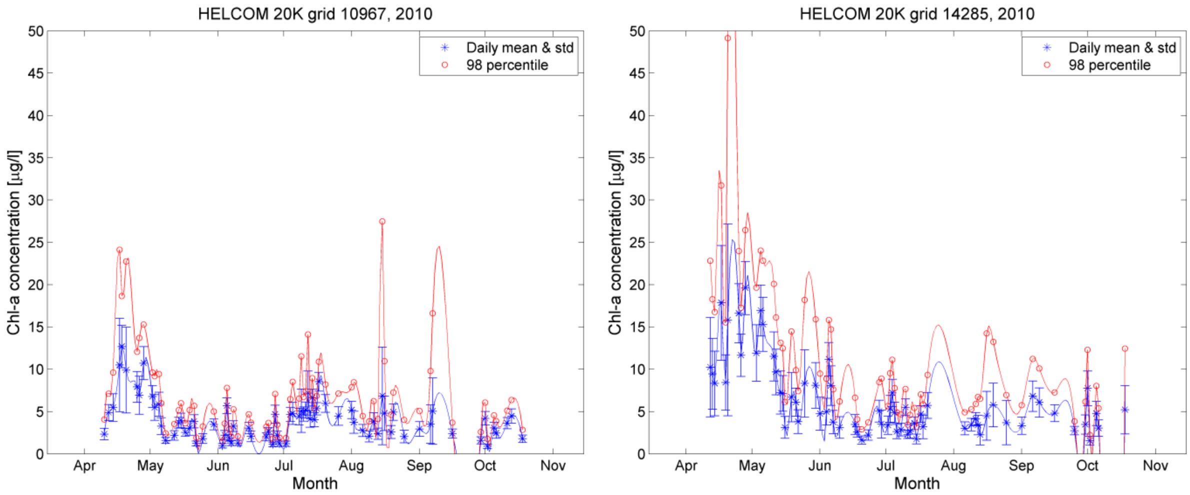

Figure 3. Example of time series of mean, standard deviation (blue stars and bars) and 98 percentile (red dots) chl-a observations by MERIS (years 2010) produced for HELCOM 20km grids, 10967 and 14285. Both grids represent Gulf of Finland. The lines are spline interpolated daily values obtained using non-cloudy EO observations.

RESULTS

To increase the accuracy of the spring bloom indicator, the method is currently being adjusted to HELCOM 20 km gridded data. These sub-areas are used to define spring bloom accurately on different parts of the assessment areas. Currently years 2006-2009 are ready. Initial values for the assessment areas in Table 2 are based on these years. Once the dataset for 2007-2011 is ready, the indicator values in Table 2 will be updated to correspond to the whole assessment period.

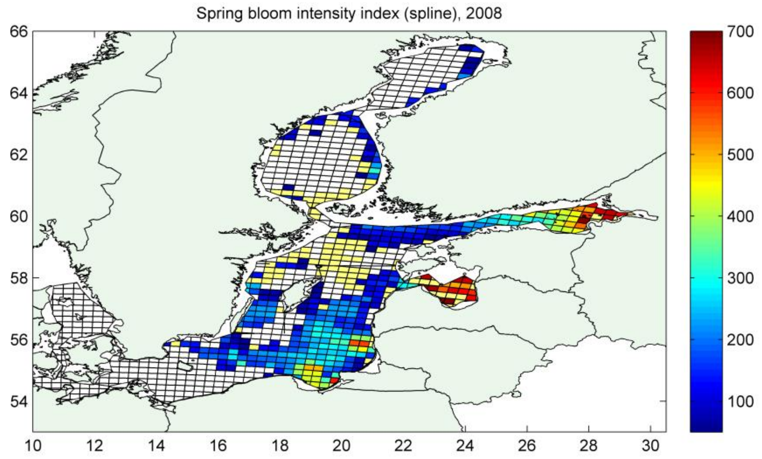

Figure 4. Example of spring bloom indicator values calculated for HELCOM 20 km grids, 2008.

Table 2: *GES targets, present concentration (currently as average of years 2007-2009), will be complemented with data from years 2010-2011 once dataset is finalized. After that status will be defined for the open-sea basins.*

HELCOM_ID	Sub-basin	Target (µg l-1)	Average index 2007-2011*	Average 2007-2011 (µg l-1)*	STATUS
SEA-001	Kattegat	Under progress	NA	NA	sub-GES
SEA-002	Great Belt	Under progress	NA	NA	sub-GES
SEA-003	The Sound	Under progress	NA	NA	sub-GES
SEA-004	Kiel Bay	Under progress	NA	NA	sub-GES
SEA-005	Bay of Mecklenburg	Under progress	NA	NA	sub-GES
SEA-006	Arkona Sea	Under progress	NA	NA	sub-GES
SEA-007	Bornholm Sea	Under progress	148,11	6,17	sub-GES
SEA-008	Gdansk Basin	Under progress	346,65	10,3	sub-GES
SEA-009	Eastern Gotland Basin	Under progress	151,32	7,82	sub-GES
SEA-010	Western Gotland Basin	Under progress	148,37	6,17	sub-GES
SEA-011	Gulf of Riga	Under progress	735,67	14,48	sub-GES
SEA-012	Northern Baltic Proper	Under progress	69,89	6,21	sub-GES
SEA-013	Gulf of Finland	Under progress	458,82	9,62	sub-GES

SEA-014	Åland Sea	Under progress	40,94	5,75	sub-GES
SEA-015	Bothnian Sea	Under progress	94,54	6,75	sub-GES
SEA-016	The Quark	Under progress	83,34	5,89	sub-GES
SEA-017	Bothnian Bay	Under progress	107,71	7,71	sub-GES

Long-term development

The longest time series on spring bloom intensity index can be derived from Alg@line data (Figure 2) for the Gulf of Finland (Fleming & Kaitala, 2006). In addition, there is modelling work under progress to hindcast spring bloom for the 20th century. The reliable determination of chl-a concentrations during spring bloom period using EO data is possible from year 2003 on. Once the time series of 2003-2011 are ready, the trends and status based on the trend will be defined for HELCOM assessment areas (SEA-7 – SEA-17). During initial study in the framework of MARMONI project, the status (trend) was defined increasing for the Gulf of Riga, and decreasing/no trend for the Gulf of Finland.

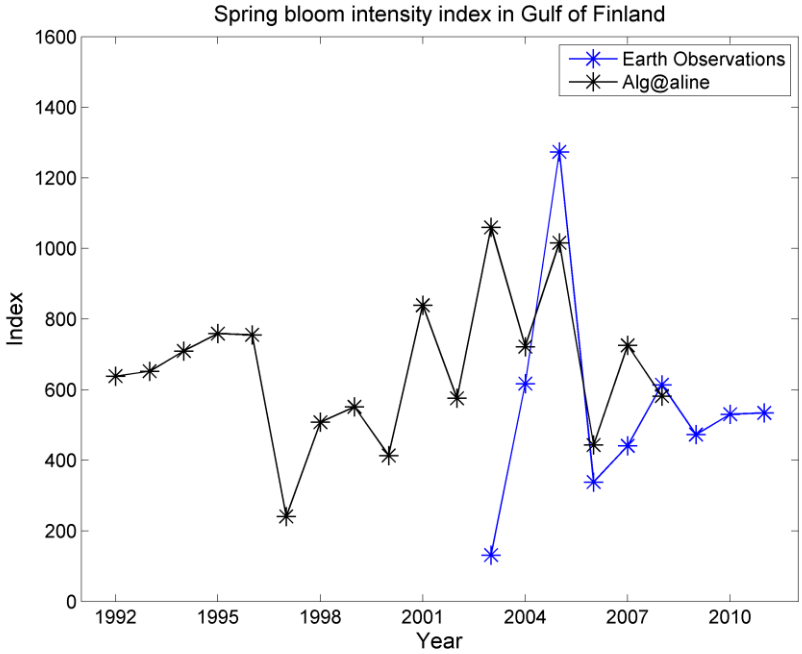

Figure 5. The development of spring bloom indicator on the Gulf of Finland using EO and Alg@line measured chl-a concentrations during 1992-2011. Black line represents Alg@line intensity index and blue line EO (MERIS data) intensity index. Figure represents the earlier version of spring bloom indicator (MARMONI project).

MONITORING REQUIREMENTS

Requirements

Spring bloom indicator requires sufficient amount of data during the spring period, so that the start, end and intensity of the bloom can be defined. It does not require daily observations, as caps can be filled using spline interpolation. In principle, the method can be used for any data that observes chl-a concentrations with sufficient frequency, such as Alg@line (Fleming and Kaitala 2006) or EO data.

The satellite instrument for the development of the spring bloom indicator method was MERIS (Medium resolution imaging spectrometer) onboard ENVISAT satellite. MERIS instrument overpasses are daily, thus daily observations are available for all non-cloudy areas and periods. Typically non-cloudy observations cover the whole Baltic Sea weekly. The ground resolution of the instrument is 300 m, i.e. one pixel on the image corresponds to 300m x 300m acreage on water.

Historical MERIS data will serve as basis for method development. The method is directly applicable for the forthcoming OLCI (Ocean and Land Colour Instrument) that is the most prominent instrument for Baltic Sea water quality detection after its launch (estimated during late 2015) onboard Sentinel 3A satellite.

Gaps

The current EO dataset starts from the beginning of April. Thus, spring bloom period in the southern Baltic Sea is not yet present in the study data. The method itself is applicable to any sea area in the future. MERIS instrument has not been operating after April 2012. Forthcoming instrument OLCI onboard Sentinel 3a satellite will replace MERIS data approximately during 2016. Thus, during years 2012-2015 similar data is not available. In principle, MODIS instrument data can be used for the period 2012-2015, but has not been tested for the time being.

DESCRIPTION OF DATA AND CONFIDENCE

[Under progress]

Metadata

Data source: The EO dataset used for deriving spring bloom intensity indexes is based on MERIS time series (years 2003-2011). The dataset is available, processed and archived at SYKE. MERIS L1A reprocessing version 3 was used as input data (available from EOLI-SA service by ESA (https://earth.esa.int/web/guest/eoli). MERIS L1A reflectances were processed to chl-a concentrations using a BEAM blug-in processor MERIS Case-2 Water Properties Processor, FUB (version beam-wew-water-1.2.10, Schroeder et al., 2007). The original geo-location information of MERIS data was complemented with AMORGOS 3.0 (Accurate MERIS Ortho-Rectified Geo-location Operational Software, by ACRI). Images are available in EUREF (WGS84) coordinates system. Cloud masking was performed semi-automatically by first using Beam MERIS cloud processor (v1.5.203), modified to use only "ocean" neural network type on the Baltic Sea. The cloud mask was quality-checked and complemented manually when necessary. The ground resolution of the instrument is 300 m.

Description of data: Spring bloom intensities can be calculated annually for each HELCOM 20 km grid and jointly for the assessment area. In addition to the intensity index indicator value, also annual mean chl-a concentration for the spring bloom period is suggested to be added to the database.

Geographical coverage: Baltic Sea, most of the observations are on the northern Baltic Sea. Geographic coordinates (WGS84) Latitude [58.747 66.020] Longitude [15.465 30.986]

Temporal coverage: The EO data includes observations made between April - October, during the period 2003 - 2011.

Data aggregation: Spring bloom estimate has been calculated using daily MERIS data. The daily observations (pixels) have been aggregated to daily statistics for each HELCOM 20 km grid. Spring bloom indicator is defined for each grid. In addition, the annual indicator value is aggregated from the grid based indexes for each assessment area.

Further work required

The work continues with complementing calculations to cover the HELCOM grid based spring bloom indicator for the periods 2003-2005 and 2010-2011. In addition, Alg@line data can be used as complementary data source in areas where EO data is not available (mostly cloudy periods). There is on-going study for using modelling approach to determine GES.

The indicator can utilize observations of the forthcoming EO instruments (e.g. OLCI instrument onboard Sentinel 3a satellite by European Space Agency, estimated to be launched on late 2015). After OLCI data becomes operationally available, the spring bloom indicators can be calculated for years 2016 on.

Arrangements for up-dating the indicator

Indicator can be updated annually after the spring bloom period.

View data

The spring bloom dataset will be made available by SYKE once it is in final form.

PUBLICATIONS AND ARCHIVE

Relevant publications

Ferreira, J.G., Andersen, J.H., Borja, A., Bricker, S.B., Camp, J., Da Silva, M.C., Garcés, E., Heiskanen, A.S., Humborg, C., Ignatiades, L. 2011. Overview of eutrophication indicators to assess environmental status within the European Marine Strategy Framework Directive. Estuar. Coast. Shelf Sci. 93,117-131

Fleming and Kaitala 2006. Phytoplankton spring bloom intensity index for the Baltic Sea estimated for the years 1992 to 2004. Hydrobiologia 554:57-65.

Gohin, F., Saulquin, B., Oger-Jeanneret, H., Lozac'h, L., Lampert, L., Lefebvre, A., Riou, P., Bruchon, F., 2008. Towards a better assessment of the ecological status of coastal waters using satellite-derived chlorophyll-a concentrations. Remote Sensing of Environment, 112, 3329-3340.

Platt T., Sathyendranath S., (2008). Ecological indicators for the pelagic zone of the ocean from remote sensing, Remote Sensing of Environment 112 (2008), 3426–3436.

Platt T., Sathyendranath S., Forget M.-H., White III G. N., Caverhill C., Bouman H., Devred E., Son SH., (2008).Operational estimation of primary production at large geographical scales, Remote Sensing of Environment, 112, 3437–3448.

Schroeder T., Schaale M., Fischer J., (2007). Retrieval of atmospheric and oceanic properties from MERIS measurements: A new Case-2 water processor for BEAM. International Journal of Remote Sensing, 28 (24), 5627–5632. http://dx.doi.org/10.1080/01431160701601774.

Verliin, A., Auniņš, A., Jaanus, A., Kuresoo, A., Stīpniece, A., Lappalainen, A., Ruuskanen, A., Minde, A., Müller-Karulis, B., Amid, C., Kokkonen, E., Gorokhova, Ē., Krūze, E., Martin, G., Sundblad, G., Piepponen, H., Hällfors, H., Nygard, H., Bārda, I., Jurgensone, I., Attila, J., Näslund, J., Kotta, J., Lesutiene, J., Kaljurand, K., Torn, K., Kostamo, K., Jürgens, K., Herkül, K., Uusitalo, L., London, L., Saks, L., Luigujoe, L., Nilsson, L., Rostin, L., Alberte, M., Lehtiniemi, M., Anttila, M., Vetemaa, M., Ogonowski, M., Kallasvuo, M., Koskelainen, M., Pärnoja, M., Kurkilahti, M., Demereckiene, N., Wijkmark, N., Heikinheimo, O., Klais, R., Svirgsden, R., Anttila, S., Hällfors, S., Lehtinen, S., Junttila, S., Strake, S., Möller, T., Talvik, Ü., Jermakovs, V., Fleming-Lehtinen, V. 2015. List of developed and proposed indicators for the assessment of marine biodiversity in the Baltic Sea. In: Martin, G., Fammler, H., Veidemane, K., Wijkmark, N., Auniņš, A., Hällfors, H., Lappalainen, A. (eds.) The MARMONI approach to marine biodiversity indicators : Volume II : List of indicators for assessing marine biodiversity in the Baltic Sea developed by the LIFE MARMONI Project. Tallinn, University of Tarto. P. 23-51. Estonian Marine Institute Report Series; 2014, 16. ISBN 978-9985-4-0873-5 (print), 978-9985-4-0874-2 (pdf), ISSN 1406-023X