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Table of contents

Introduction

Underwater acoustic navigation system RedWAVE is designed to provide navigational data (absolute geographical coordinates and depth) for various underwater objects in the submerged state: remotely operated underwater vehicle (ROV), manned submersible, autonomous underwater vehicle (AUV), as well as divers in case of using devices in diver's version.

The principle of the RedWAVE system is similar to the principle of the global satellite navigation systems GPS and GLONASS. The main difference is that small and easy to install floating buoys RedBASE serve as navigation satellites and retransmit satellite navigation signal. In this case, the coordinate is generated directly on the navigation receiver, which is an acoustically passive device. Such system organization allows to simultaneously provide navigation data to an unlimited number of navigation receivers with the support of one set of buoys in one water area.

1.System structure

1.1. RedBASE: GNSS-equipped sonobuoy

1.1.1. General information

GNSS-equipped sonobuoys are designed to organize a long navigational base in the water area which provides RedNAV navigation receivers work.

The long navigational base is formed by four RedBASE buoys that allow an unlimited number of RedNAV diver's navigation receivers to operate in the same water area. Buoys are placed on the surface in the water area and anchored. Although the buoys have a small positive buoyancy, they are not designed for direct mounting to the anchor rope. To unload the buoy from the weight of the anchor rope must be used fenders (or floats) same to the weight of the rope.

Figure 1[1] shows the recommended scheme for deployment a buoy in the water area.

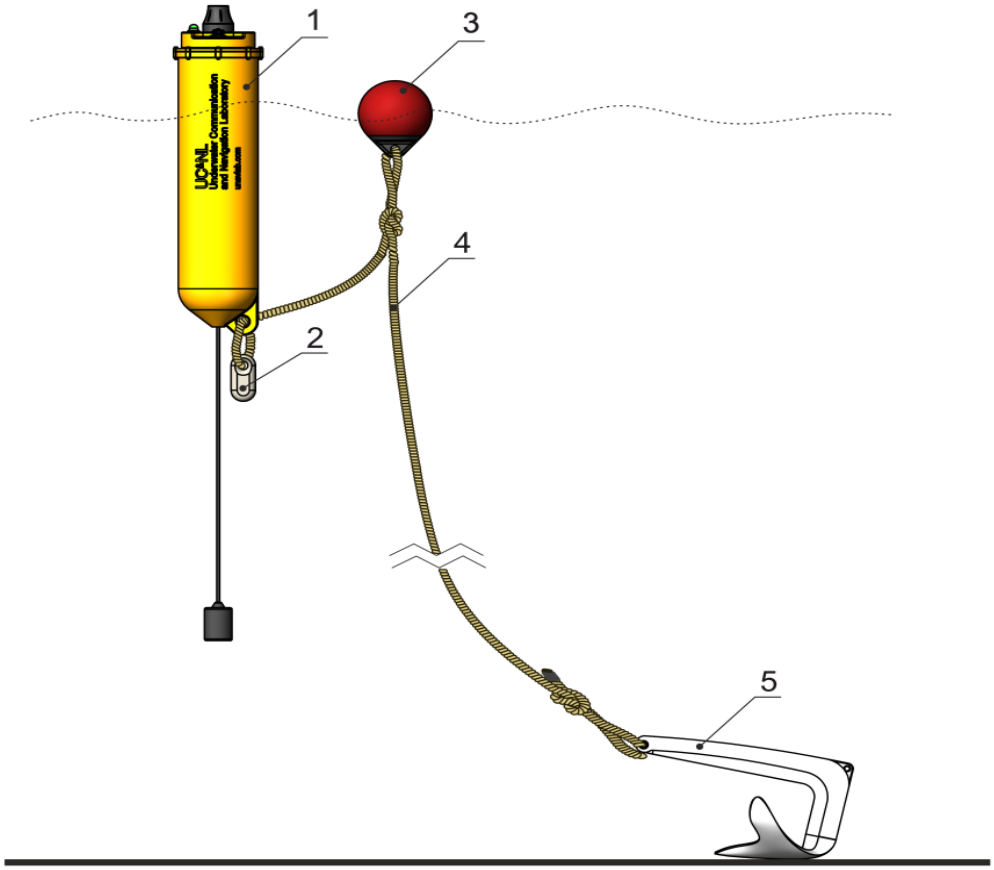

Figure 1 - recommended deployment scheme for the RedBASE buoy.

In Figure 1 numerals indicate:

1 - RedBASE GNSS-equipped sonobuoy, 2 - additional load[2], 3 - float, 4 - anchor rope, 5 - anchor.

[1] Images may slightly differ from the supplied products, as the manufacturer is constantly working on improving the characteristics and making changes to the design

[2] Used only in underloaded version

Figure 2 shows a general view of the GNSS-equipped sonobuoy controls.

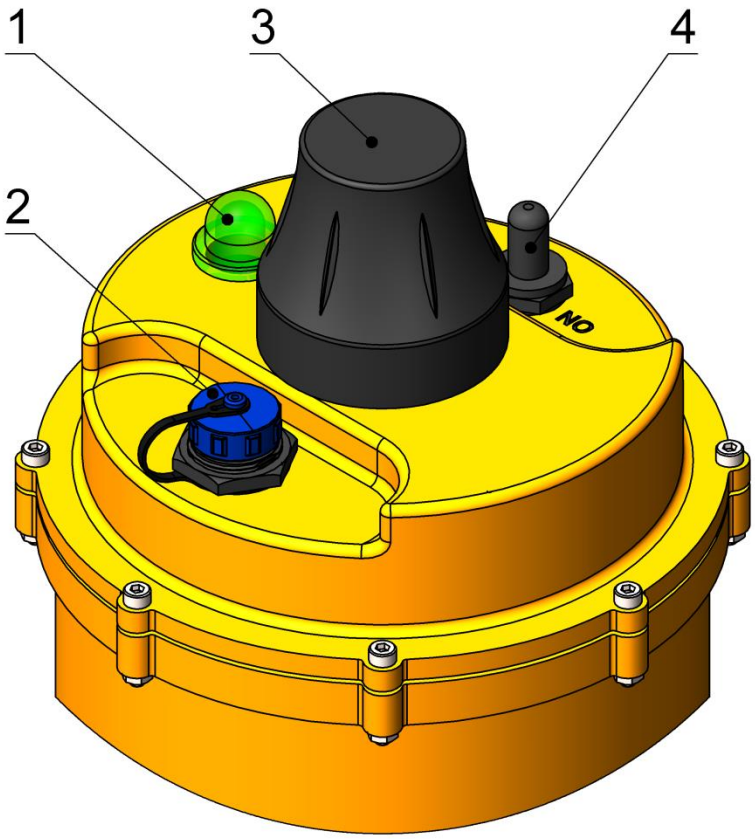

Figure 2 – Layout of connectors and devices on the buoy cover:

1 – indicator, 2 – charging connector, 3 – GPS/GLONASS antenna, 4 – tumbler switch

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1.1.2. Operating modes and light indication

Buoys in each set (the set contains four buoys) have different addresses from 1 to 4. When the buoy is turned on by tumbler switch 4 (see Figure 2), it shows its number in the set via indicator 1. The number of flashes corresponds to the buoy number. If the buoy is equipped with a light-signal mast, the flashes will be duplicated on it. In all other modes with a critically low charge except for self-shutdown the light-signal mast flashes once every 5-6 seconds.

The buoy goes into working mode after reporting its number. If the buoy battery is charged, the indicator will light up continuously until the integrated GPS / GLONASS receiver detects signals from the satellites of the global satellite navigation system. After that, it will flash 1 time in 4 seconds. The number of flashes in this case also corresponds to the buoy number in the set.

If the buoy battery charge is less than 20%, the indicator will flash 1 time per second. The number of flashes in this case also corresponds to the buoy number in the set. If the user has noticed one flash per second, the buoy should be turned off and put on charge as soon as possible. Long-term operation with a discharged power supply is not allowed.

If the battery is in a critical discharge state, the indicator will also be turned off as well as the buoy after reporting its number. The buoy must be immediately put on charging in order to avoid the failure of the built-in power source.

1.1.3. Storage and maintenance

Buoys do not have special requirements for storage and maintenance, except for the following:

- When using a salt and/or heavily soiled water necessary to conduct desalting (sediment and washing in fresh water);
- Do not use any organic solvents, strong acids, alkalis and other corrosive substances;
- If necessary, washing in household soap solutions is possible;
- The impact or significant static loads both on the buoy body and on the controls (the GPS / GLONASS antenna and the hydroacoustic transmitter) are not allowed;
- For prolonged storage (more than 1 month) it is necessary to recharge the devices to prevent degradation of the built-in lead battery;
- Do not use third-party chargers;
- It is not allowed to store in the switched-on state;

- Avoid strong (with a radius less than 5 cm) bending of the hydroacoustic transmitter cable;
- Do not store in the inverted state or hang on a load-bearing eyelet ;
- Before work, it is necessary to carefully inspect the rubber cap of the tumbler switch for its integrity. It is strictly prohibited to use the device with a damaged rubber cap of the tumbler switch ;

1.2. RedNAV: diver's navigation receiver

1.2.1. General information

RedNAV is the only device in the world that provides so called true underwater GPS for divers. It allows divers to determine their own geographic location in submerged state wirelessly.

Operating the RedNAV in many ways similar to the work with GPS/GLONASS receiver, but instead of GNSS satellites, it needs four RedBASE sonobuoys deployed that allow an unlimited number of RedNODE/RedNAV devices to function at the same time and at the same place.

Unique functionality and usability make RedNAV ideal for recreational diving, archeological, biological and any other scientific and technical underwater works.

RedNAV device has a wrist mount and an acoustic receiver that can be mounted on the air tank. Wireless connection to a PC and wireless charger make RedNAV extremely easy to use and maintenance.

1.2.2. Device work and the user interface

Figure 3 shows an external view of a diver's navigator RedNAV.The device consists of an interface module mounted on the wrist of a diver and an acoustic navigation receiver coupled to the interface module via cable. The interface module contains a screen and two control piezo buttons. Button functions are displayed on the screen depending on the current mode of the device.

The acoustic navigation receiver should be mounted on the diver's shoulder or on the balloon to ensure the minimum possible acoustic shadowing. Optimum operating conditions of the acoustic receiver are achieved when there is a direct visibility between the navigation receiver and the acoustic transmitters from all four RedBASE buoys throughout their use.

Figure3 – diver's navigation device RedNAV

The device is equipped with a wireless charger and connects to a PC via Bluetooth only in the service mode (when based on the charging platform connected to the power supply).

Figure 4 shows the screen of the device in the service mode on the charging platform connected to the power supply.

Figure 4 – Diver's navigation device RedNAV. Screen display in service mode

In the service mode, the device displays:

- battery charge indicator, where each degree corresponds to 20% charge;
- charge indicator: at maximum brightness - charge goes on, at low brightness - charge doesn't go;
- Bluetooth connection indicator: at maximum brightness - connected to the application, at low brightness - no connection to the application.

Figure 5 shows the screen of a device connected via Bluetooth to a PC.

- Name of the device that will be displayed in the list of available Bluetooth devices on the PC (it has RDNV-XXXX format, where XXXX - four hexadecimal digits 0..F);
- pin code to communicate with the device using a PC (PIN: 1945)

Figure 5 – diver's navigation device RedNAV.

Screen Display in service mode. The device is connected to the PC via Bluetooth.

Once installed on the charging platform, the device automatically switches to the service mode. To increase the efficiency of the charge the screen and the Bluetooth module will be turned off automatically after 5 minutes if no buttons are pressed and there is no connection between PC and the device. To resume the Bluetooth module, remove the device from the charger and reinstall it.

Figure 6 – diver's navigation device RedNAV.

The screen in working mode, no communication with buoys

Figure 6 shows the screen of the device in the operating mode, when there is no signal from the buoys.

This mode displays the target - buoys that indicated by squares. Battery charge indicator, depth (distance from the surface) in Figure 6 is 0.0 m, the temperature in Figure 6 is 22 ° C. As there is no buoys signal, at the place of the distance and azimuth to the target the dashes "- - -" are displayed.

The symbol ">" on the button means "Next target" and the symbol "+" means "To mark the current point". When the device has no connection with buoys, these functions are not available.

Figure 7 shows the situation when the device is in working mode and there is a connection with buoy # 1. Own position is not yet specified.

Figure 7 - diver's navigation device RedNAV.

The screen in working mode. A signal was received from the first buoy.

Figure 8 illustrates the situation when the device's own position is determined. The buoy # 1 was chosen as the target (switching between the targets is done by clicking the ">" button). The distance and bearing to the target are displayed on the screen: 124 meters and 146˚, respectively.

In this case buoys, number 2 and 4 are displayed as unfilled rectangles that indicate that their built-in power supplies require a charge.

Figure 8 – diver's navigation device RedNAV.

The screen is in working mode. Own position is specified, the buoy №1 was chosen as the target

When the device's own position is adjusted, the switching functions between the targets ">" and the current position "+" are available. Pressing the "+" button will mark the current position. The response of the device to pressing the "+" button is shown in **Figure 9**.

Figure 9 – dive's navigation device RedNAV. The screen is in working mode. The device responds to the current position by pressing the "+" button.

Figure 10 shows the situation when by pressing ">" button the user selects the previously saved point (in the list under the number 1) as the target.

Figure 10 – diver's navigation device RedNAV. The screen is in working mode. The previously saved point (number 1 in the list) is selected as the target.

As in the case of buoys, the distance and bearing to the target are displayed. When navigating to a target at a distance of fewer than three meters instead of azimuth dashes "- - -" are displayed.

To turn off the device you must simultaneously press both buttons. In this case, the device will ask you to confirm the shutdown (**Figure 11**).

Figure 11 – diver's navigation device RedNAV. Request to shut down

To turn on the device and you must also simultaneously press both buttons.

1.2.3. Synchronization with PC

The device interfaces with a PC using the built-in Bluetooth module. The Bluetooth adapter on the PC must be turned on and the device must be installed on the charging platform connected to the power supply.

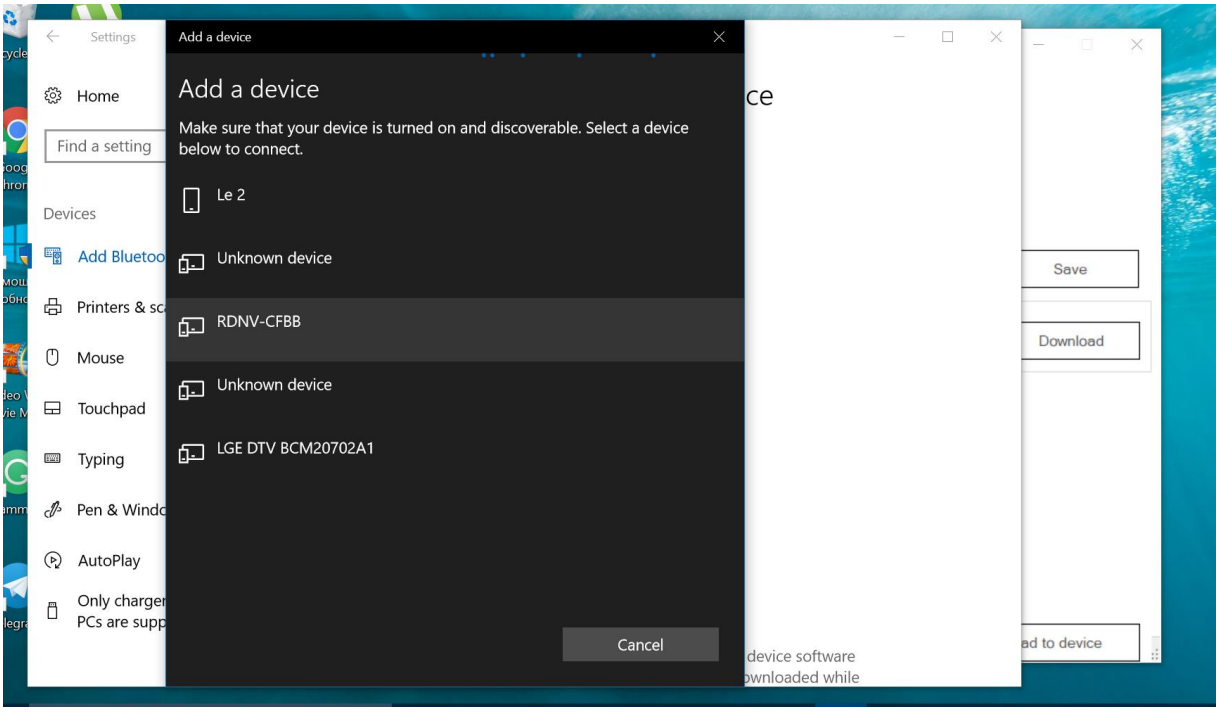

Figure 12 – Adding a Bluetooth device

As an example, consider the device connected to a PC running Windows 10. **Figure 12** illustrates a standard system dialog for adding a new Bluetooth device. The list displays the name of the device that can be seen on the screen of the device itself (in the example RDNV-4B8C).

When you click "Connect" button, the system will offer to enter a PIN code (shown in **Figure 13**).

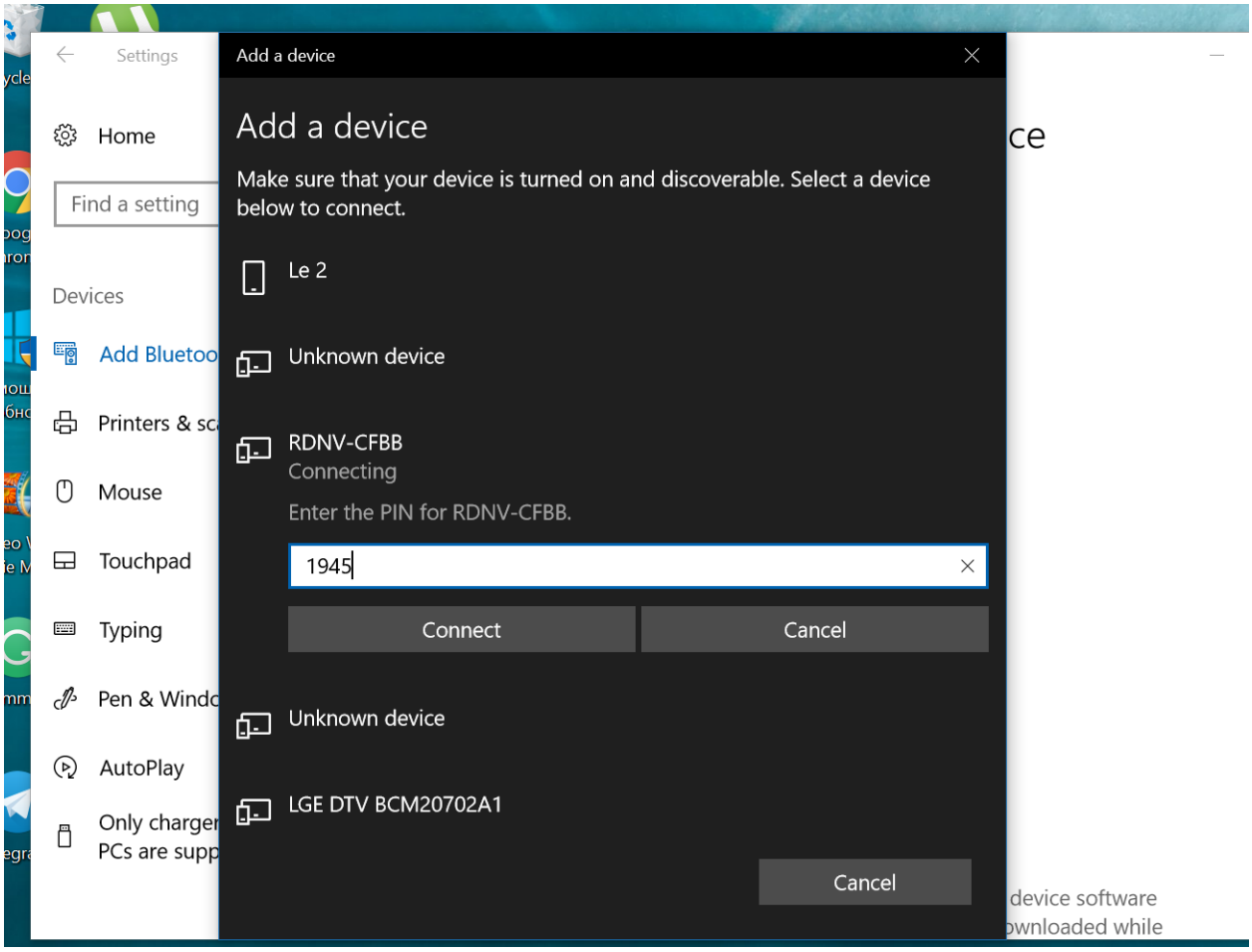

Figure 13 - Request for a pin code

The screen displays the pin code that needs to be entered to create a connection to the device (1945 in the example).

After entering the pin code and pressing the "Next" button, wait for connection with the device. After that, the dialog window should look like in **Figure 14**. The device's status is "Connected".

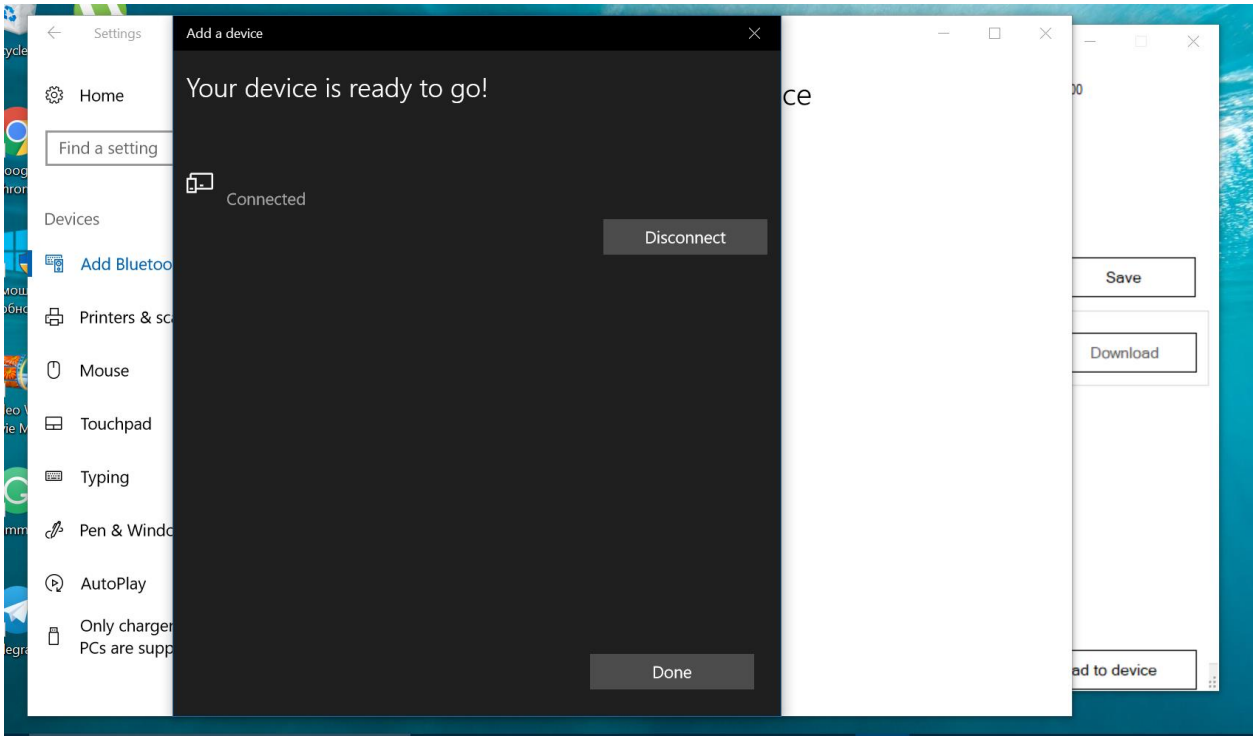

Figure 14 - The device is connected

After connecting the device, run the application RedNAV Host and it will make a connection with the device itself. When the connection is successful, the application window will display the status "Connected" in the status bar, as illustrated in **Figure 15**. The name of the device (in our case, RDNV-4B8C) appears in the title bar of the window.

The top line displays information about the device version and its serial number. Below displays information about the version of the navigation receiver and its serial number. This information is available only if the device has been switched to the service mode from the on state and not switched off on the charging platform.

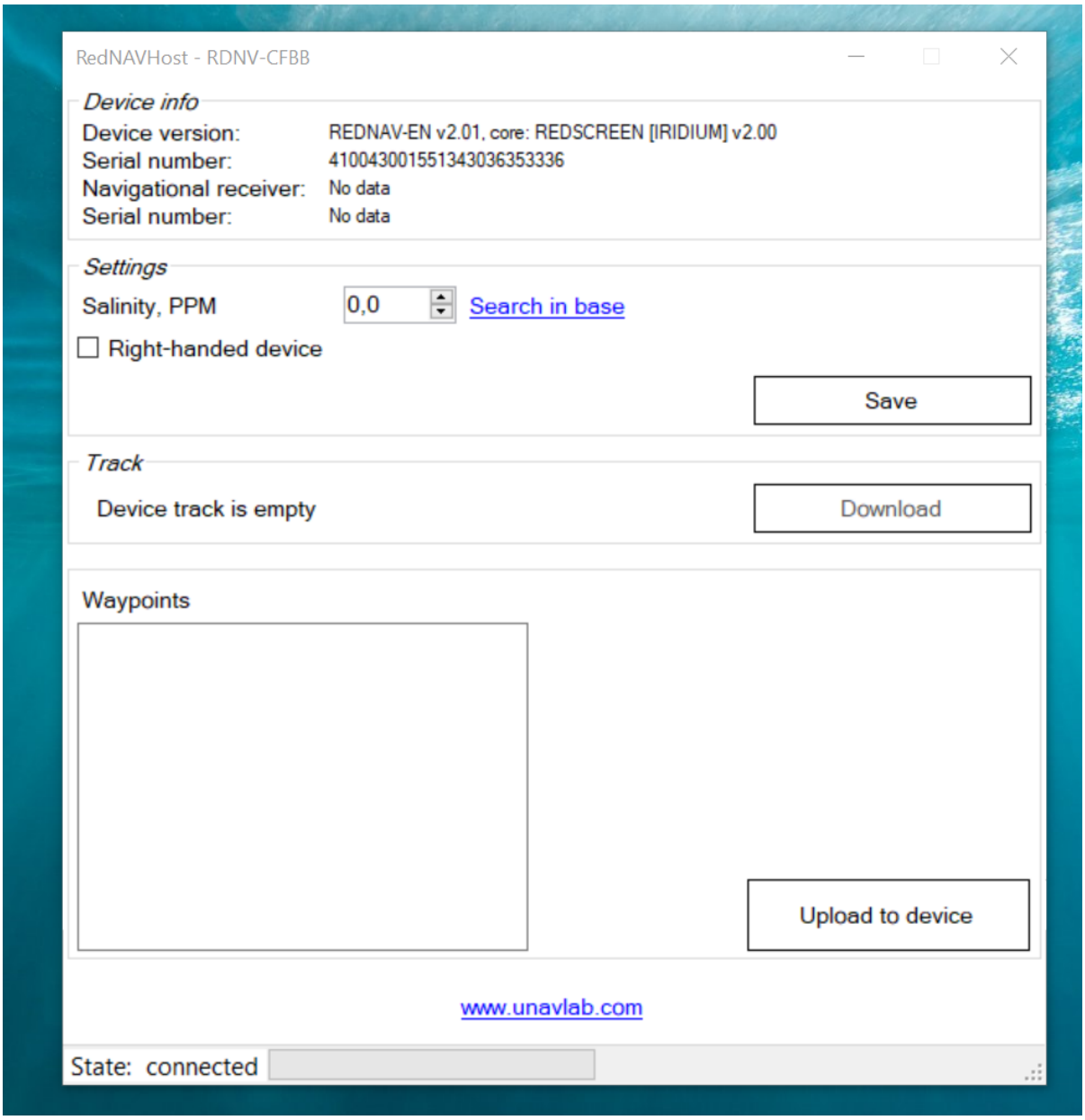

Figure 15 - the Main window of the RedNAV Host application. The device is connected and has connection with it

Once the device is connected, the user can change the settings. Diver's navigation device has a minimum number of settings. In particular, for proper operation, it is only necessary to set the salinity of the water. If the work is planned in freshwater areas, it is recommended to leave the default value of 0 ppm.

For convenience, the application contains a database of global ocean salinity for points through 1˚ latitude and longitude. To search for the salinity of the specific water area, you need to enter the geographic coordinates of the place in the dialog called "Find in the database". **Figure 16** shows the form of this dialog. After entering the location coordinates (sufficiently accurate to a degree) and pressing the "Find" button, the salinity value will be displayed at the nearest known point with the measured salinity. When the "OK" button is pressed, the detected value will be placed in the setup field of the main window.

In addition, it is possible to configure the device screen to flip with the simultaneous exchange of button functions. To do this, you need to check the "Flip Screen" checkbox in the main application window.

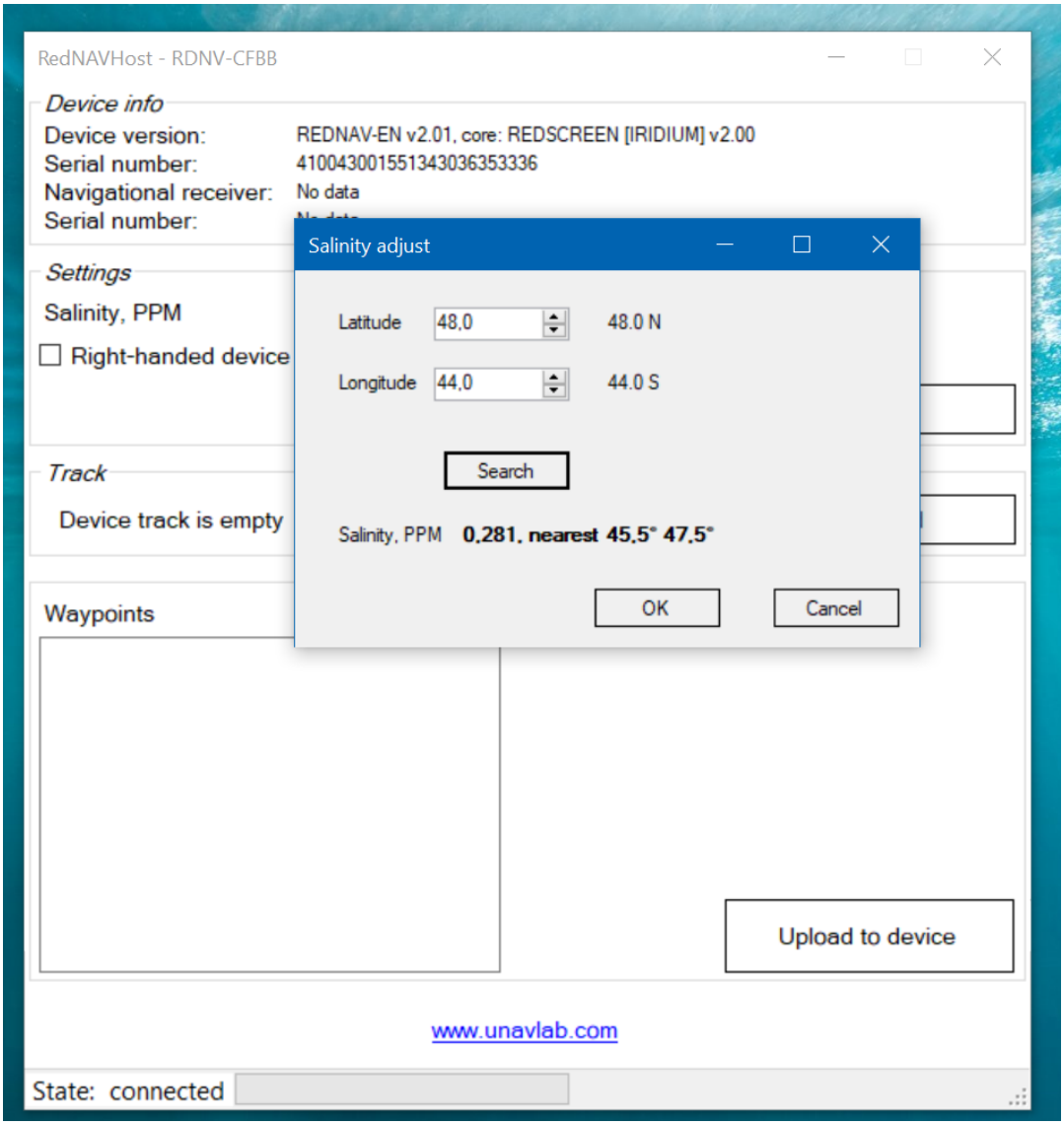

Figure 16 - Salinity selection dialog

To load the settings into the device, you need to click the "Save" button (see **Figure 15**).

To unload the track of buoys positions and saved points recorded by the device, use the "Unload" button (see **Figure 15**). This situation is illustrated in **Figure 17**.

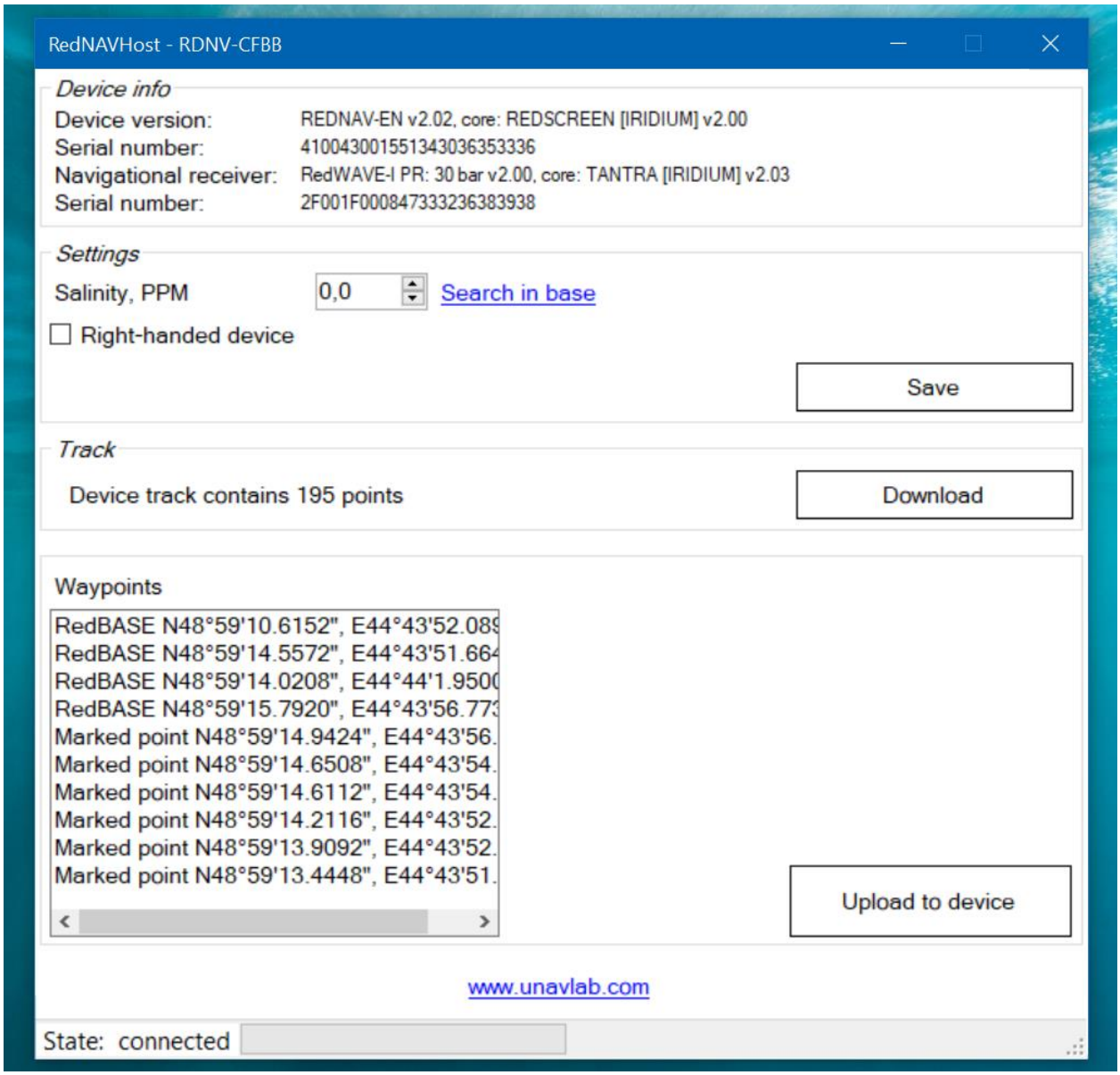

Figure 17 - Unloading the track

After clicking the "Unload" button while the track is being unloaded from the device, the remaining buttons will become unavailable, and the progress of the operation will be displayed in the application status bar.

After the end of the download, the application will offer to save the uploaded data using a standard system dialog. The file name will be a name that is composed of the current system time and date, as shown in **Figure 18**.

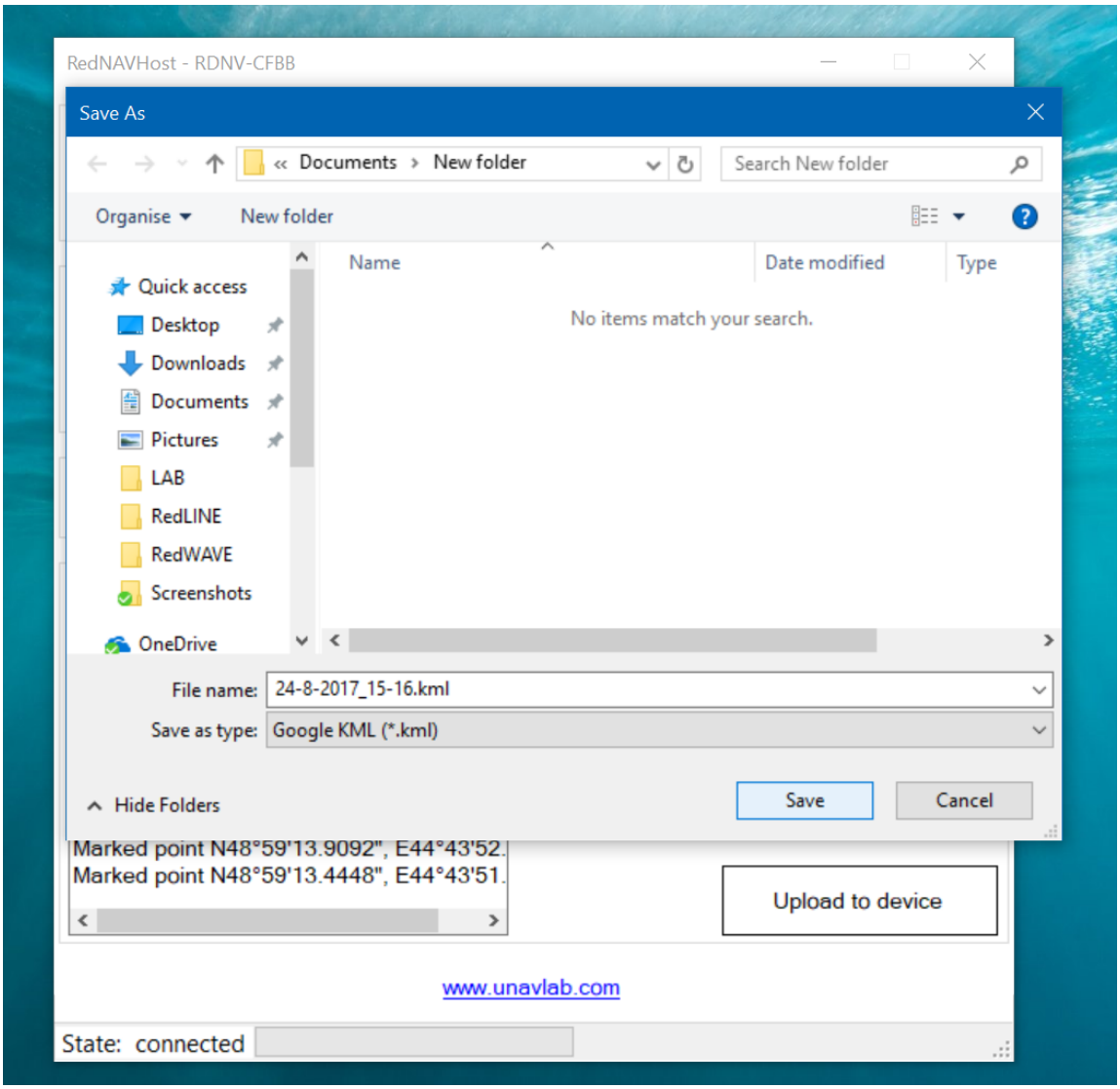

Figure 18 - Dialog for track saving

After saving the data, the application asks the user whether to clear the track from the device.

Attention! After clearing the track from the device, it will be absolutely impossible to restore the track.

To work with waypoints user should use the context menu invoking it with the right mouse button on click the "Waypoints" group, as shown in **Figure 19**.

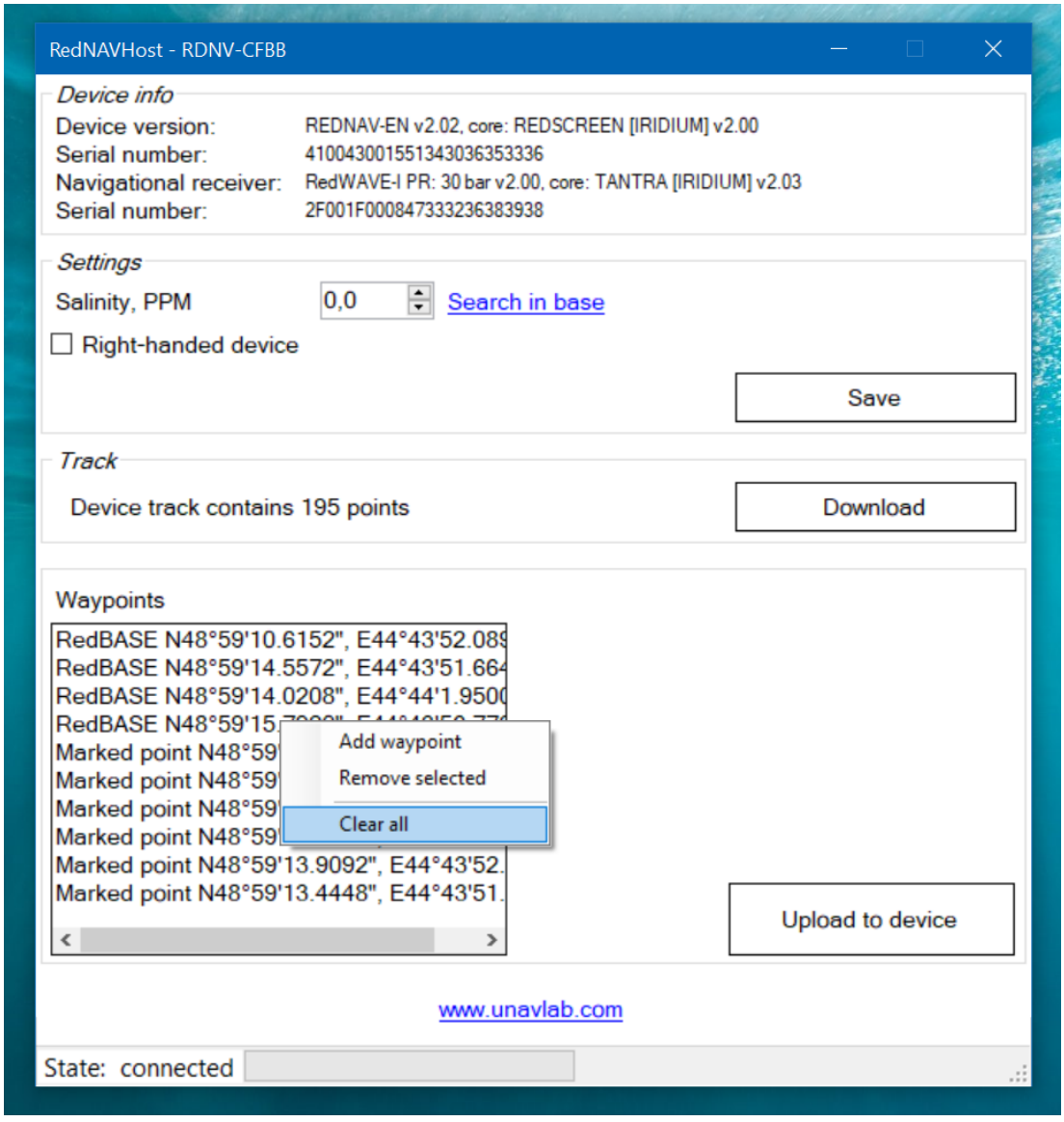

Figure 19 - Working with waypoints

The manually added points can be edited by selecting an added point and then using the appearing panel on the right (see **Figure 20**).

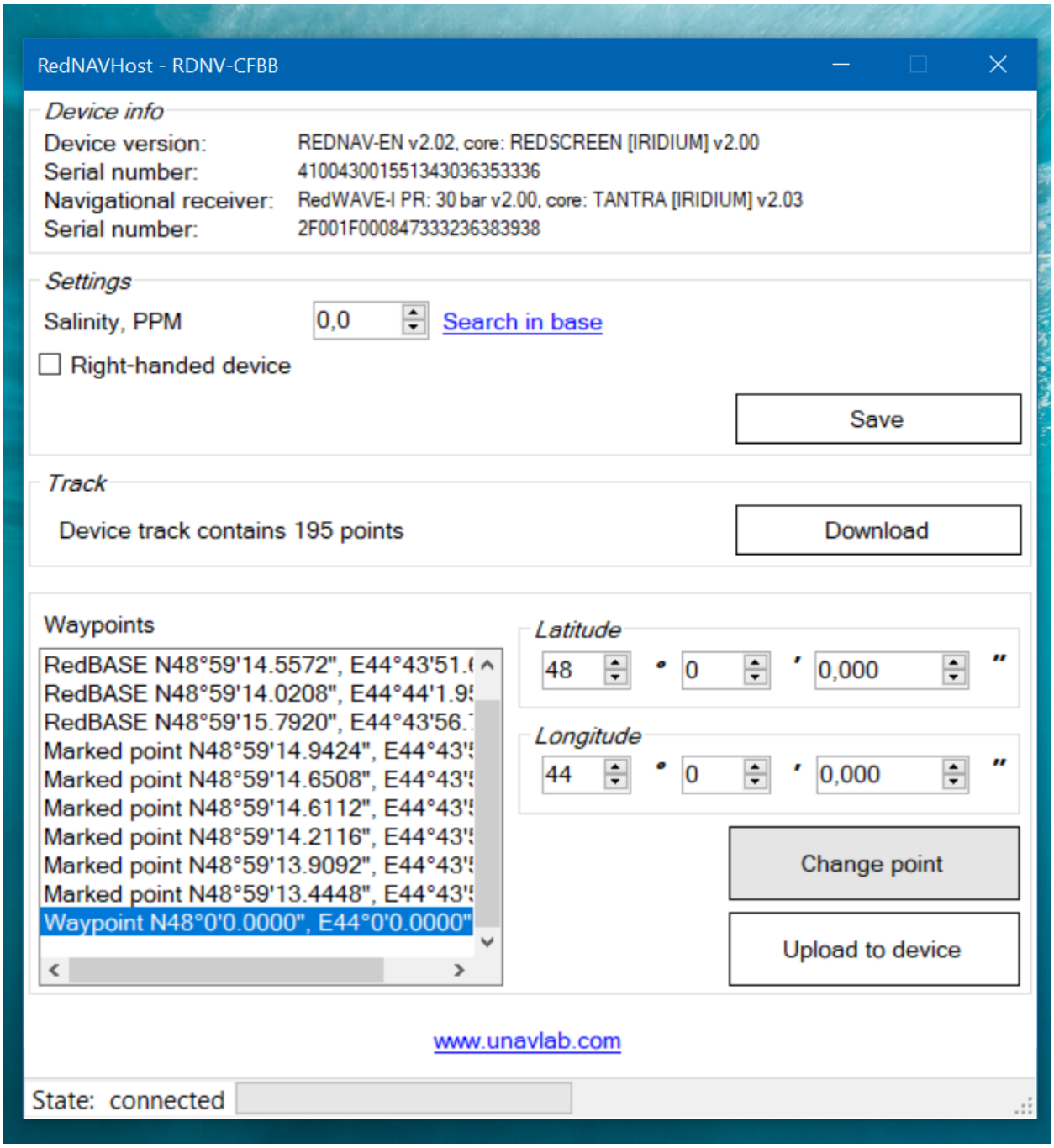

Figure 20 - Editing an added waypoint

To synchronize the list in the "Waypoints" panel with the device, you must click the "Upload to device" button. To clear all waypoints in the device, you must delete them in the list, and then click the "Upload to Device" button and answer yes to the application request.

1.2.4. Storage and maintenance

Diver's navigation device RedNAV does not require special storage and maintenance conditions, except for the following:

- Avoid fully discharge the built-in battery of the device. For prolonged (more than 1 month) storage it is recommended to periodically charge the device;
- After use in salt water, the device must be carefully washed in fresh water;
- Do not use detergents or organic solvents. The dirt that occurred can be removed with a soft damp cloth. It is allowed to use soap under the condition of washing the device in fresh running water after;
- Do not leave the device permanently exposed to direct sunlight;
- The protective glass cover is made of abrasion resistant polycarbonate, but it is recommended to avoid any possible contact with the cover glass with hard (sharp) objects to prevent scratches and chips;
- Do not bend the cable connecting the interface unit to the navigation receiver, with a radius of less than 5 cm;

2. Effective deployment of a long navigational base

The deployment of a long navigational base in the general case consists of setting and switching on four RedBase sonobuoys in the water area where there is supposed to be a work with RedNAV devices. Each of the four buoys in the set differs from others by the address that defines the code channel of the hydroacoustic communication over which the buoy transmits the data.

Attention! It is not allowed to simultaneously operate several sets of buoys in the same water area, as well as to use buoys from different sets. In this case, correct positioning and system availability are not guaranteed!

The correct installation of buoys implies compliance with three basic conditions:

1. Ensuring a safe and stable buoy position on the water surface;
2. Providing a good view of the celestial hemisphere for satellite-based navigation systems installed on buoys;
3. Providing direct visibility between the acoustic transmitting antennas of the buoys and all RedNAV receivers in a submerged position.

Let's examine them in more detail:

To ensure **the first condition**, floating buoys should be anchored to make sure they remain safe from wind and currents. The weight of the anchor rope should be perceived as an additional float and the buoy should not take any additional vertical load.

Figure 1 shows the recommended scheme for mounting the RedBASE buoy at anchor.

It is not recommended to use the system when sea waves exceed 1.5 points.

When sea waves are 2 or more points, the use of the system is highly discouraged and the manufacturer is not responsible for damage to individual devices of the system, their loss, and malfunction, etc.

The second condition is due to the fact that the RedBASE buoys are retransmitters of the satellite navigation signal. They have built-in combined GPS / GLONASS receivers and for the correct operation of the navigation base, it is necessary to ensure a good reception of the satellite navigation signal on buoys. Due to this, buoys should be located at the maximum distance from various obstacles, which can affect the quality of the received satellite signal. For example, metal hulls of vessels, mooring walls, etc. RedBASE buoys are equipped with a light indication. When switched on, the warning light constantly flashes until the first clarification of the geographic location of the buoy is made by the built-in GPS / GLONASS receiver. After that, the warning light goes off and after a while (on average 1-2 minutes) the buoy goes into working mode. In this case, the warning light flashes once every four seconds (the number of short flashes by the number of the buoy). And if the built-in battery of the buoy is very discharged, then the lamp flashes every second. In this case, the buoy should be immediately put on charging, otherwise, it can lead to the failure of the built-in battery.

Typical time of the buoy transition into the operating mode (the time before the warning light stop flashing constantly) in open water is no more than 2-3 minutes. If the lamp does not stop flashing for a longer period of time, you must change the location of the buoy.

Multiple repetitions of this situation in the open space where nothing can interfere with the passage of the satellite navigation signal is the reason for contacting the manufacturer.

The third condition is determined by the physical principles of the operation of a long navigation acoustic base. Since RedNODE devices calculate their own position by evaluating the timing of the acoustic signals from the RedBASE buoys to the RedNODE devices, their correct operation requires constant direct visibility between the acoustic transmitters of all four RedBASE buoys and the operating RedNODE devices. This refers to direct visibility through the water column.

The optimal position of buoys in the water area is a convex quadrilateral that limits the work site. The distances between buoys should not exceed 700 meters. Working with RedNODE devices outside the long base figure is possible, but because of the physical nature, it is more likely to obtain the best accuracy and reliability of navigational data within the long base figure.

From the point of view of the long navigational base, the worst position is when three or more buoys are placed in a line.

When planning the arrangement of buoys, it is also worthwhile to avoid such arrangements in which the depth of the buoys position significantly differs from the depth of the positioned objects. For example, when the work is expected at the narrowest point of the river with a gently sloping beach then buoys should be located in the deep part of the river. However, it is worth remembering that too small figure of the navigational base (less than 10-30 meters) and/or its strong elongation (the ratio of the sides of the quadrilateral is more than 4-5) lead to a decrease in accuracy and/or less sensitivity in some directions.

The location of buoys in ice holes is allowed if the body of the device is not pressed with ice and the acoustic antenna is provided with sufficient precipitation (the radiating antenna of the buoy must be located deeper than the lower edge of the ice, at least 0.5 meters).

It is not recommended to operate the acoustic antenna for a long time in the air. Ensure the free position of the acoustic antenna in its working position without touching the anchor rope or any other objects.