Investigation of Bottom Habitant Diversity in Great Peter Bay Using Semi AUV TSL

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Abstract - **One of IMTP projects is connected with investigation of structures and functioning of marine ecosystems on the shelf. Information from different sources is accumulated in database for integrated analysis and study of dynamic of ecosystem elements functioning. Important task here is connected with aggregation search and colony density estimation of bottom objects by methods that do not disturb the conditions and biosphere of inquiry subjects.**

IMTP and TINRO-centre in 2001- 2002 years fulfilled conjoint research for diversity investigation and colony density estimation of bottom objects in Great Peter Bay using semi autonomous underwater vehicle TSL [1]. TSL is a specialized self-propelled underwater vehicle with data-command link to operator on supporting ship by light fiber-optical cable. Operations were conducted on depth up to 90 meters. Approach to ecology monitoring on marine shelf by semi AUV TSL use and some experimental results are described in the paper.

1. INTRODUCTION

Ecological monitoring of water areas is intended for hydrobiological, hydrochemical and hydrophysical characteristics investigation with subsequent mapping of the data. Evaluation of water environment condition, benthic animals and algae distribution density has great theoretical and practical value for ecosystem research.

The advantage of unmanned underwater vehicle /UUV/ application for this task solution can be reduced to the following [3]. The underwater vehicle equipped with TV camera and a system of sensors allows to obtain the objective and documented information about biocenosis in general and its plant component in particular. It makes possible to evaluate a character of bottom, a level of species dominance, evidence of their state and density of population. The information can be obtained on long lines in preset areas in the form of video record and sensor data with the positioning, current time and date. This allows to use it for multiple and comparative analysis, for studies of species density and population dynamics, and for data processing with different mathematical methods.

According to the research tasks an UUV can be equipped with a system of sensors for TV survey and water parameters measurements (temperature, salinity, transparency, concentration of oxygen and phytoplankton, etc.). This UUV consists of on-board control system, supporting automatic and manual modes of operation, propulsion system, providing the wide vehicle motion modes including the hovering, positioning system, allowing to determine the location and orientation, based on acoustic and on-board autonomous navigation systems.

2. TECHNOLOGY OF ECOLOGICAL DATA COLLECTION USING TSL

Bottom survey on base of TSL use was fulfilled by next way. Before shallow water operation the survey area is divided into regions. The supporting ship is anchored in the center of each region for inspection. Region size depends on fiber optical cable length that TSL reel was equipped. Then regions are inspected using sensors and TV system. Operational distance of TV system depends on water transparency and ranges from 0.5 to 8 m on the shelf. For probability restriction of AUV fiber optical cable tangling around bottom objects (rocks, grass and industrial targets) two shifted opposite tacks trajectories were used.

After run into hydrobionts aggregation, digital photo system is switching on by command from on ship operator. In this mode the AUV moves by fixed tack and catches still photo images with programmed period. The data received during AUV operation (bottom color video and still photos, sensor measurements and motion parameters) are stored for next analysis.

Let consider for estimation of covered square by video survey, that height of motion above bottom is $\boldsymbol{h = h1 + h2}$ = 1 meter (Fig. 1) and running way – $\boldsymbol{L}$ = 350 meters. Region of view in perspective vision system is trapezium. The mean line M of trapezium is calculated from expression:

$$\boldsymbol{M = h*tg(\varphi/2)\{1/cos(\gamma+\phi/2) + 1/cos(\gamma-\phi/2)\}.}$$

Suppose that φ = 77, ϕ = 59 and γ = 40 deg. – vision angles in water of used video camera in horizontal, vertical planes and slope angle. So the mean line of trapezium is M = 3.13 m and square of survey region – S ≈ M*L = 3.13*350 ≈ 1100 m^2. Time for one launch including submerge and ascent operation depending on sea conditions was 1.5 – 2.5 hours. Mean days number of diving equals four and surveyed square is about 4400 m^2.

Digital color photos received by TSL photo system have format of 1020*1024 pixels. Each photo is provided with

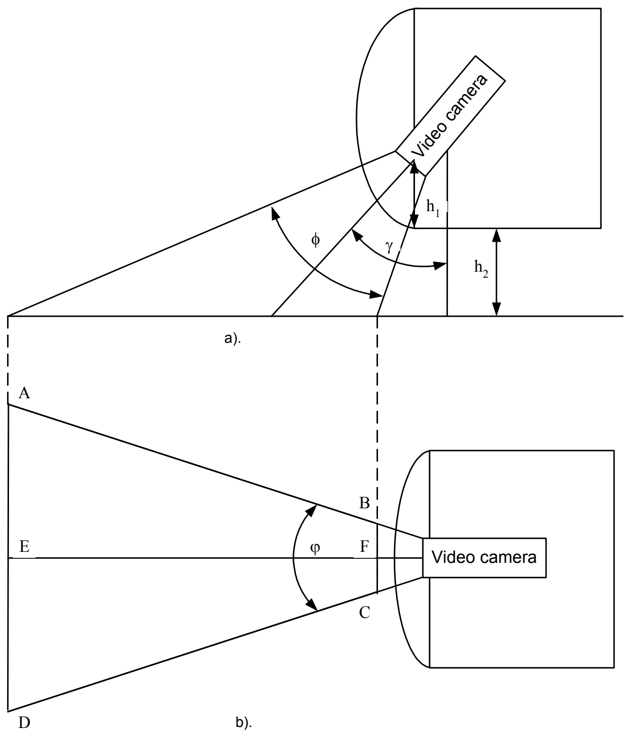


Fig.1. Vision angles of TSL video camera in vertical a) and horizontal b) planes.

set of data that consist of geographical coordinates (latitude and longitude) of image position, height above bottom and depth of vehicle motion, current date and time, the temperature and horizontal size ***L*** of bottom region reflected on still photo. Real size ***m*** of object in image frame is defined from expression:

$$\boldsymbol{m = L*k/R},$$

where ***k*** and ***R*** are measured on photo image the object size and frame horizontal size.

Bottom habitant density is defined on base of consequent digital photo image processing, received on inspecting tacks. Firstly the number of bottom inhabitants of definite species is calculated for each photo image. Then graphs of inhabitants change along the way depending time or still photo number are built. The summary bottom square used in calculations, whole number and mean size of inhabitants are also defined.

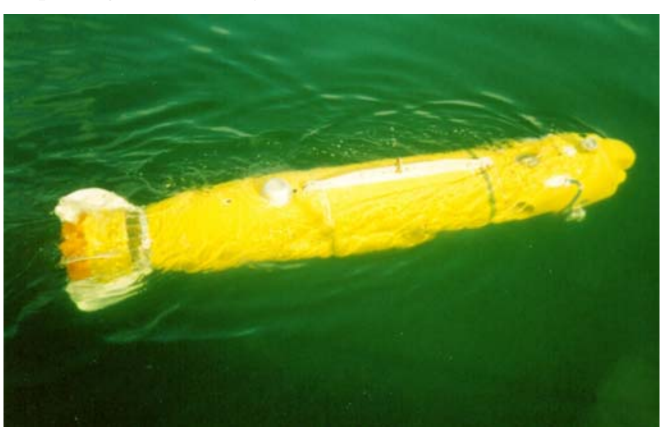


Fig.2. Semi AUV TSL after surfacing.

The data received can be used for ecological monitoring and quality control of water reservoirs, seashore zones and bays by means of preset parameters mapping and for tasks of aquaculture as well as for determination of benthic animals population density and state of ecosystems.

3. INSTRUMENT FOR ECOLOGICAL DATA COLLECTION

Semi AUV TSL is a specialized self-propelled underwater vehicle with data-command link to operator on supporting ship by fiber-optical cable (Fig.2.). The vehicle is rigged with color video and digital photo cameras. Video camera is installed on pan and tilt platform and allows a forward vision in wide angle. Photo camera is arranged on the vehicle's bottom and oriented vertically down.

Vehicle propulsion system consists of six thrusters (two in the nose and four in the stern TSL sections). It provides wide number of motion modes including hovering. Cable freely winds off from the reel (Fig.3.) when TSL is moving. Dimensions and specifications of TSL are shown in table 1.

Table 1

Dimensions and specifications of TSL

Length	3030 mm
Diameter	533 mm
Dry weight	320 kg
Max speed	2 m/s
Max depth	200 m
Batteries	24 V/70 Ah
Endurance (v=1.2 m/s)	10 hours
Max length of fiber optical cable	5 km

TSL control system is distributed and consists of on board control system or autopilot on the vehicle and operator

Fig.3. Reel with fiber optical cable in the stern part of TSL.

Fig.4. TSL graphic user interface control window.

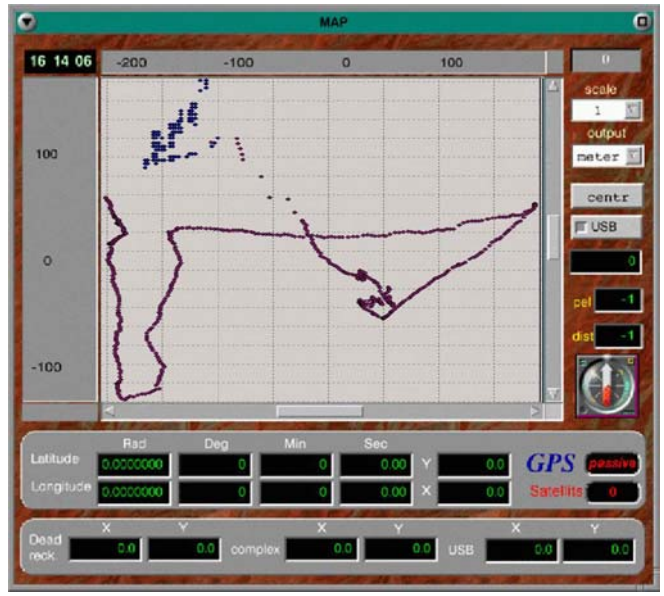


Fig.5. TSL graphic user interface map window.

console on the supporting ship. Operator console based on PC is intended for input of control information and TSL operation mode by multi windows graphic user interface /GUI/ (Fig.4) in real time and also for accumulation and visualization of TSL sensor data.

The manual and automatic modes of TSL control system operation are possible for region inspection. In the manual mode an operator organizes TSL trajectory for region covering by setting of TSL motion parameters (height or depth, velocity and heading) from console. For trajectory covering of region in automatic mode the operator initializes one of the standard missions, corresponding to the predefined trajectory. In this case an operator can stop the mission execution at any time, investigate the detected target in manual mode and then continue mission fulfilling.

TSL control system automatically stabilizes mission height or depth, head and motion velocity. On base of down, forward and slope echo sounders on board control system allows automatic obstacle avoidance in vertical plane.

Transmission of current video and photo images and sensors measurements to operator console through the fiber optical cable provides the real time search and inspection of objects on the bottom and in water column.

Positioning of TSL and supporting ship trajectories is fulfilled on base of joint data processing from on ship GPS, USBL positioning system and TSL on-board autonomous navigation system. It enables to calculate the TSL trajectory coordinates and detected object positions in geographical coordinate system with error about 10 meters.

The map with result of one of TSL operation is illustrated on Fig.5, where in upper left corner is shown the supporting ship trajectory and in lower half of the map is depicted the trajectory of TSL.

4. SOME MARINE OPERATION RESULTS

Bottom survey for hydrobionts population investigation was fulfilled in 2001 – 2002 using semi autonomous underwater vehicle TSL. The investigation results received in 2001 were published in [2]. In this part we describe the data, received during expedition from 31 of August to 17 of October in 2002. Scientific ships "Impulse" and "Gastello" took part in the operations.

4.1. Objects for survey

Bottom hydrobiont population in the Great Peter Bay consists of algae, sea-water grass, echinoderms, shellfish and crayfish. During bottom survey there were identified:

- algae – Ahnfeltia tobuchiensis, Codium fragile, Sargassum pallidum, Sargassum miyabei, Ptilota filicina, Ulva fenestrata, Laminaria cichorioides;
- echinodermata – Stichopus japonicus, Cucumaria japonica, Strongylocentrotus nudus, Strongylocentrotus intermedius, Asterias amurensis, Patiria pectinifera, Aphelasterias japonica, Ophiura sarsi;
- sea-water grass – Zostera asiatica, Phyllospadix iwatensis;
- shellfish - Mytilus edulis, Modiolus difficilis, Swiftopecten swifti, Patinopecten yessoensis;
- crayfish - Pandalus latirostris.

One of objects for survey was aggregation of *Stichopus japonicus on Ahnfeltia tobuchiensis* in the Stark strait and near Ivantsev cape. Survey in August – September let to detect just some alone representatives of *Stichopus japonicus* on the layer of *Ahnfeltia tobuchiensis.* In the middle of October survey reveals considerable increasing of *Stichopus japonicus* on the layer of *Ahnfeltia tobuchiensis.* It proves the fact of observation that in warm summer period of time *Stichopus japonicus* located inside of layer of *Ahnfeltia* *tobuchiensis* but in cold late autumn period it goes up to the surface of *Ahnfeltia tobuchiensis* layer.

Other object of investigation was aggregation of *Cucumaria japonica.* The survey results prove the fact of *Cucumaria japonica* migration during seasons. Also there were visually detected some anomalies in evolution of *Asterias amurensis* (number of rays is more than five) and of *Patiria pectinifera*.

4.2. Bottom habitant density estimation

Bottom inhabitant density estimations were fulfilled for aggregation of *Stichopus japonicus on Ahnfeltia tobuchiensis* field and for aggregation of *Cucumaria japonica.* Height of *Stichopus japonicus* survey was changed from 0.6 to 1.5 meters, depending of *Ahnfeltia tobuchiensis* layer thickness. Depth of operation region changes from 9 to 11 meters. Some consequent digital photo images with *Stichopus japonicus on Ahnfeltia tobuchiensis* field are shown on Fig.9.

Graph of *Stichopus japonicus* quantity depending of bottom image ordinal number is shown on Fig.6. TSL photo system operation period was τ = 8 sec, velocity was equal to 0.3 m/s. It was used 56 photo images, length of inspecting tack was 135 meters. The estimation result of *Stichopus japonicus* density – 0.59 objects per square meter (m^2). Calculation parameters are shown in Table 2.

Graph of *Cucumaria japonica* quantity depending of bottom image ordinal number is shown on Fig.7. Depth of operation region changes in ranges 42 – 44 meters. TSL photo system operation period was τ = 8 sec, velocity was equal to 0.3 m/s. It was used 40 photo images, length of inspecting tack was 96 meters. Some consequent digital photo images with *Cucumaria japonica* are shown on Fig.8. The estimation result of *Cucumaria japonica* density – 7.62 objects per square meter (m^2). Calculation parameters are also shown in Table 2.

Table 2

Object	Number of image processed	Common square, m^2	Inspection tack length, m	Summary object number	Object mean size, sm
Stichopus japonicus	56	20.2	135	12	9.7
Cucumaria japonica	40	12.2	96	93	11.2

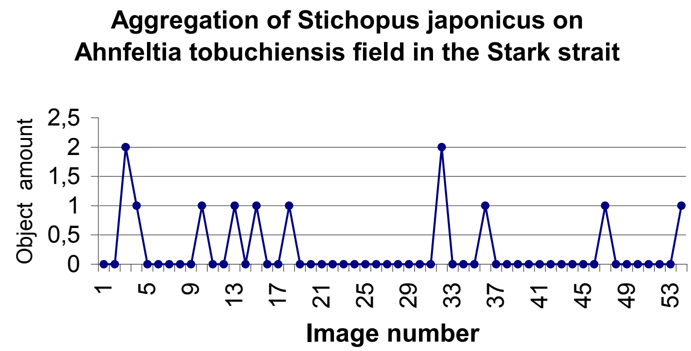


Fig.6. *Stichopus japonicus* quantity depending of bottom image ordinal number.

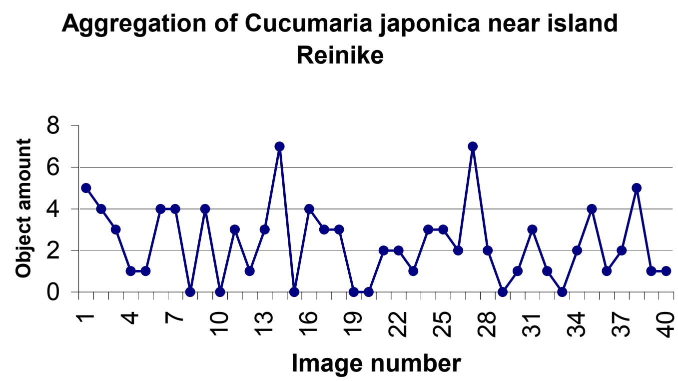
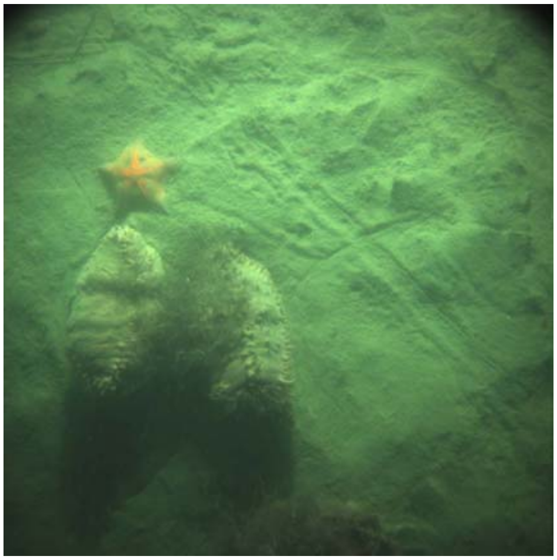


Fig.7. *Cucumaria japonica* quantity depending of bottom image ordinal number.



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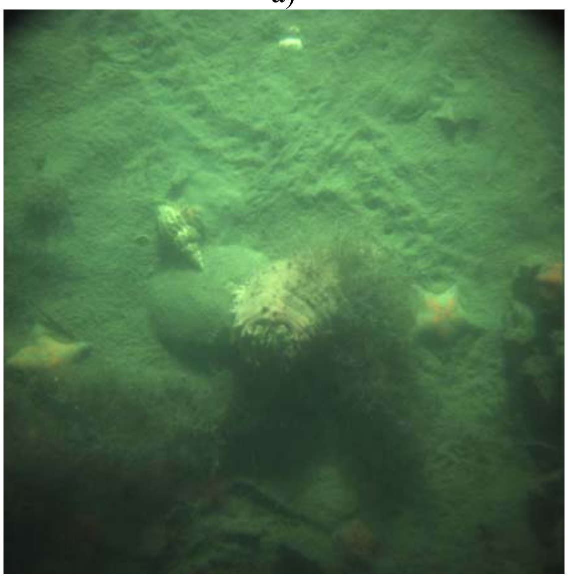

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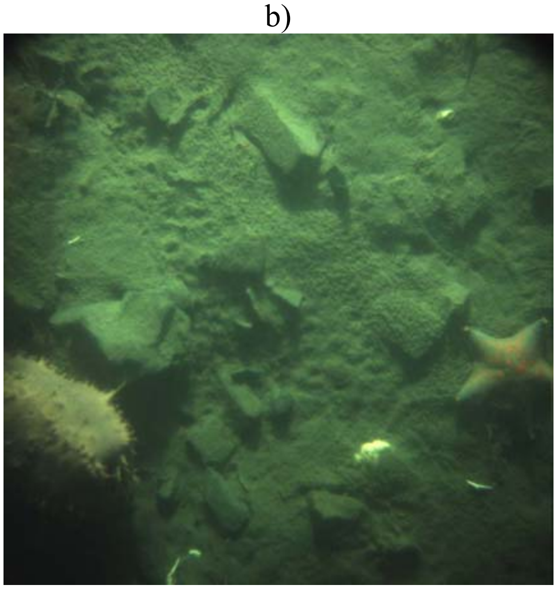
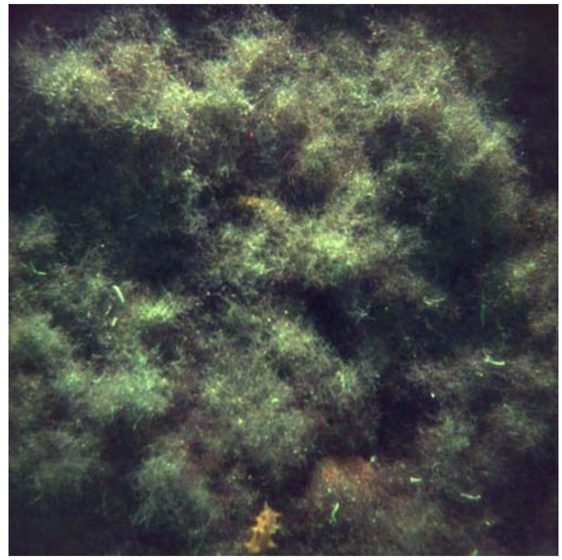


c)

Fig.8. Aggregation of *Cucumaria japonica.*



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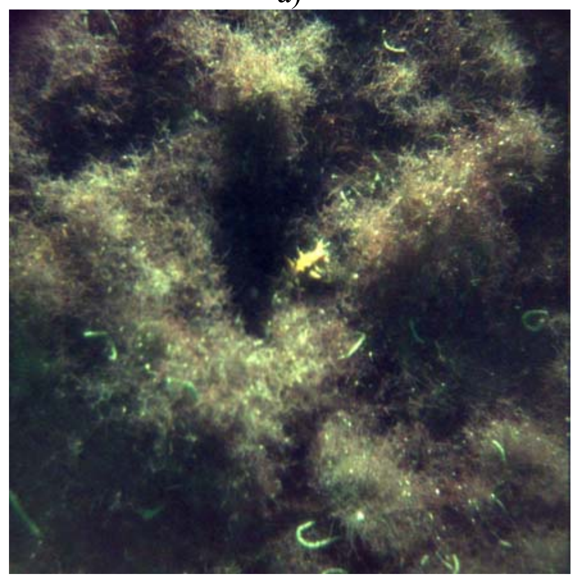

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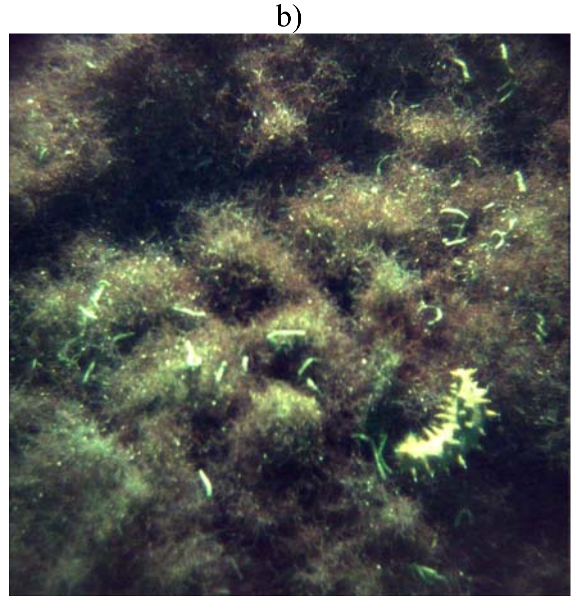

c)

Fig.9. *Stichopus japonicus* on *Ahnfeltia tobuchiensis* field.

5. CONCLUSIONS

The technology of ecological monitoring of water areas using unmanned underwater vehicles /UUV/ is comparable with a method of diver survey but has some important advantages connected with greater efficiency and informativity, unrestricted possibilities of area and depth investigations.

The UUV usage allows to increase research reliability because of subjective estimation minimizing and to improve the hydrobiont aggregation mapping precision and it's reserves evaluation. Video images and still photos received using TSL let to recognize the bottom hydrobionts species, to recognize their square density and size of objects, to define the bottom soil type. Use of UUV gives an opportunity of bottom hydrobionts efficient utilization by making choice of more appropriate regions of catching. Bottom hydrobionts behavior observation in natural conditions opens prospect for environmental protecting actions fulfilling.

Operations among big rocks and bluffs near island Reinike and Verkhovskogo prove possibility of TSL use in condition of complex relief. Probably the usage of unmanned underwater vehicles is the only way to fulfill such kind of operations in this conditions.

Possibility of underwater robot operation from coast and small ship makes lower cost of work performance. The technology given allows to decrease the minimum of risk for the personnel connected with performance of the underwater research works.

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