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Marine Macrophytic Algae of the Western Sector of North Pacific (Russia)

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1. Introduction

Marine algal flora of the western coasts of Bering Sea is studied non-uniformly, i.e. to a variable degree in different areas. Perhaps, algae of the Commander Islands are studied more thoroughly as compared to the other areas of the Russian Pacific. The data on marine algae of the Islands were presented in many published works by the Russian authors. The comprehensive survey of the literature on the Islands' marine flora was given in our papers (Selivanova & Zhigadlova, 1997 a, b, c). Thereafter we continued our floristic and taxonomic studies on the Commander Islands and published many new papers: Selivanova, 2001 a, b; 2008 a, b, c; 2009; Selivanova & Zhigadlova, 2000; 2003; 2010; Zhigadlova, 2009.
In contrast to Commander Islands algae of the continental part of the Bering Sea are studied rather poorly. Though floristic investigations began there above 200 years ago information on algal flora and structure of benthic communities of this area is still scanty. Remoteness and inaccessibility, severe climate and ice conditions, and a short navigation season make this area very inconvenient for natural studies, so they were episodic and uncoordinated. Practically no seasonal field observations have been conducted there, no marine biological stations have ever existed, and scientific expeditions have been infrequent and sporadic. Therefore information on benthic algae of the area is limited. Special publications on this subject are rare (e.g.Vinogradova, 1973a; 1978; Perestenko, 1988; Zhigadlova & Selivanova, 2004), although data on the marine algae of this area may be found in some general taxonomic, floristic and hydrobiological studies (e.g. Kongisser, 1933; Petrov, 1972, 1973; Vinogradova, 1973b, 1974, 1979; Vinogradova et al., 1978; Vinogradova & Perestenko, 1978; Kussakin & Ivanova, 1978; Perestenko, 1994).
The most detailed and contemporary information on marine algae of the Russian part of Bering Sea is given in our recent publication (Selivanova & Zhigadlova, 2010). This work however was published in Russian in a book with a small number of copies so it is scarcely available to phycologists outside Russia. Partially data on algae of western part of Bering Sea (from Ozernoi Gulf to Dezhnev Cape) was presented earlier in my work (Selivanova, 2002), its electronic version is still available at the address: http://ucjeps.berkeley.edu/constancea/83
Data from this publication are cited in the species list of Bering Sea algae presented in a current paper. However some part of this information has already become out-of date due to considerable and fast changes in the algal systematics caused by the application of

molecular-genetic studies in phycology in the latest decade. So our main purpose was to make the inventory of the flora of the western Bering Sea on the basis of our personal collections in conformity with new world data in algal taxonomy and nomenclature.

We studied benthic algae of the western part of Beirng Sea that belongs to the administrative region – Kamchatskii Krai, including Koryak Autonomous District (from Ozernoi Gulf to Dezhnev Bay) (Fig. 1). Water areas northwards of it located on the territory of Chukchi Autonomous District (Anadyrskii Gulf, north of Dezhnev Bay to Bering Strait) were unstudied by us. However data on the algae of this area may be found in the papers of Vinogradova (1973a, b), Tolstikova (1974), Kussakin & Ivanova (1978); Perestenko (1988; 1994) but the inventory of marine algae of this region is uncomplete, and additional floristic and taxonomic studies are necessary.

It should be noted that in spite of better knowledge on algae of the Commander Islands as compared to other areas of western coasts of Bering Sea inventory of their flora is still not finished either because of the difficulties of collection of algae, especially subtidal ones, in this remote hard-to-reach and little-inhabited area. Besides that the general taxonomic base is insufficient and there are still unsolved nomenclatural problems.

That is why the species list of marine benthic algae of the Russian sector of Bering Sea presented in the current work in tables (Table 1-3) should be still treated as preliminary. It is not only due to the permanently renovated information on algal systematics but also due to more careful examination and re-identification of our material and finding of new species especially having sub-microscopic size.

Moreover collections of algae on the studied area were carried out in a short period of time (mostly in August-September) that also makes our list insufficient and obviously its completion needs additional field expeditions in other seasons. Necessity to continue studies on marine algae of the western coasts of Bering Sea is also caused by the threat of extermination of algal species as a result of uncontrolled harvest of marine bioresources. The fact is that rich and diverse vegetation on the shelf of this area attracts increasing attention of the commercial sea fishery organizations in the recent decade of years.

2. Materials and methods

The list of algae presented in the paper is based on phycological material collected by the author during expedition of the Laboratory of Hydrobiology of KBPIG in the Bering Sea in 1988. The material was collected from August through October on the littoral fringe during low tides, with the help of a long hook called "kanza" from the depths of 1 to 3 m, and with usage of SCUBA technique from the depths of 1 to 30 m and with a dredge from deeper waters (up to 120 m). The material from Commander Islands was collected by the author during expeditions of the same laboratory annually in 1986-1992 and incidentally by individual collectors in 1997, 2007-2010. Algae were collected from April through September on the littoral fringe during low tides, and with use of SCUBA from the depths of 1-30 m. Algae cast ashore were also picked up. Material was sectioned freehand with a razor blade, placed in a drop of fresh water on the slides and examined using the light microscope. The sections were studied uncolored or stained with iodine Lugol solution. The processing of collections was conducted at Kamchatka Branch of Pacific Institute of Geography (Petropavlovsk-Kamchatskii, Russia). Material is stored in the herbarium of the above mentioned institute.

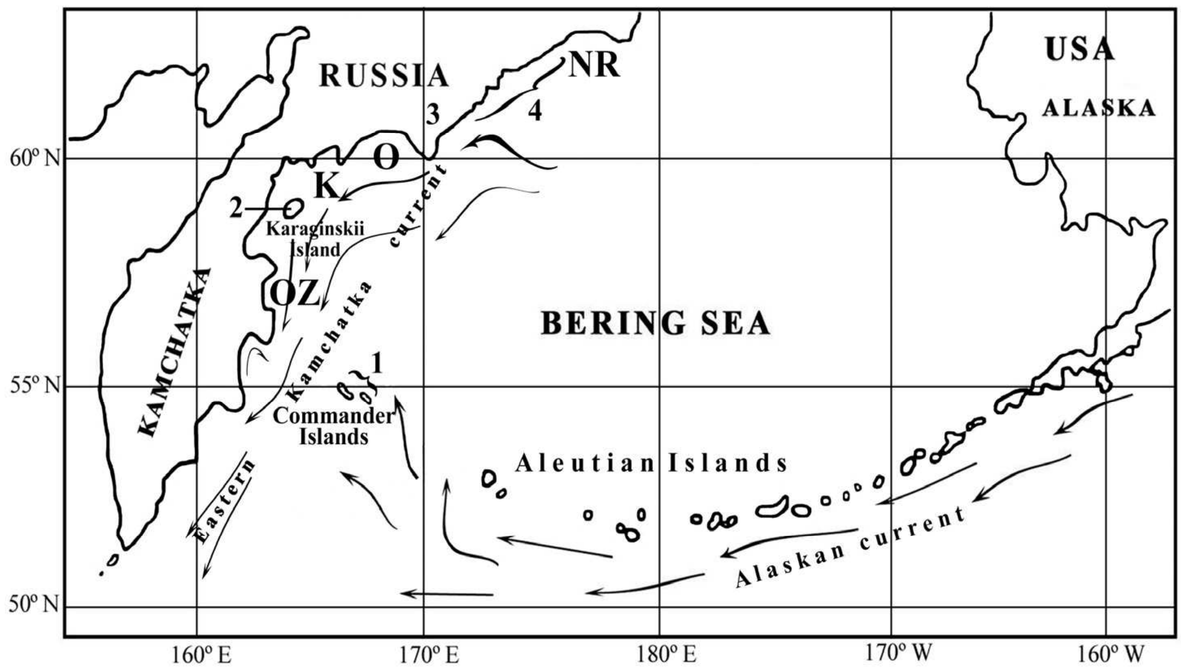

Fig. 1. A schematic map of the part of Bering Sea including Commander Islands. Arrows show the direction of the Eastern Kamchatka and Alaskan currents. Numbers correspond to the specially protected nature areas (SPNA-s) within the studied area: **1** – Commander state biosphere reserve; **2** - Reserve "Karaginskii Island"; **3** - State nature reserve of federal significance "Koryakskii"; **4** - Nature park "Beringia". Abbreviations correspond to the names of major water areas of Bering Sea where algae were collected: **NR- Navarinskii Region, O – Olyutorskii Gulf, K- Karaginskii Gulf, OZ – Ozernoi Gulf.**

3. Species composition and distribution of marine macroalgae of the upper part of the western North Pacific (continental coast of Bering Sea and Commander Islands)

Up to the present day the general list of marine benthic algae of the western coasts of Bering Sea including Commander Islands based on our own materials contains 193 species, but taking into consideration data from the literature their number totals to 209 ones: 36 species of Chlorophyta, 129 Rhodophyta and 44 Ochrophyta (class Phaeophyceae). The list is considerably enlarged as compared to the previous publications (Selivanova and Zhigadlova, 1997a, b, c; Selivanova, 2002) due to new finds of algal samples and description of new taxa.

The author's own data on the species composition of poorly studied areas of Bering Sea are supplemented with the generalized information from separate literature sources only if this information seems to be reliable. In quoting the data of the other authors I do not always share their opinion on taxonomic status of the species and their nomenclature because quite often the data cited are based on rather old literature or archieve materials, so they are outdated, not taking into account changes in the nomenclature and systematics of algae which have occurred recently. Nevertheless, they are included in the table with corrections, where it is possible, in conformity with modern taxonomic data. The original information of the other authors in the case I do not accept their interpretation of the taxa or doubt in correctness of the species identification is not included in the present list.

As it was already mentioned marine macrophytic algae of the Commander Islands are studied more thoroughly as compared to the other areas of the Russian Pacific. By the present day the species list of algae of the Islands based on our collections includes 164 species but it is still being enlarged in the process of the material processing. Recently we found there 9 species new for whole Russian Pacific coastal area (Selivanova and Zhigadlova, in press) and described a new taxon of red algae: *Gloiocladia guiryi* (Selivanova) Selivanova (2009). It belongs to the order Rhodymeniales, family Faucheaceae and appears to be the first representative of the genus and the family Faucheaceae to be reported from the Far Eastern seas of Russia though members of the genera *Fauchea* Bory et Montagne in Montagne and *Gloiocladia* J. Agardh were well known from the other areas. They were recorded from the American Pacific coasts (e.g. O'Clair, Lindstrom, 2000; Gabrielson et al., 2000, 2006), from Japan (Yoshida, 1998), Korea (Oak et al., 2005) and China (Xia, Wang, 2000). But our species still remains the only representative of the family Faucheaceae in the Russian Pacifc sector. Originally it was described as *Fauchea guiryi* Selivanova (2008c). However a taxonomic revision of the genus *Fauchea* based on morphologic and molecular-genetic data resulted in the transfer of the overwhelming majority of the species of the genus including the generitype *F. repens* (C. Agardh) Montagne et Bory de Saint-Vincent to the genus *Gloiocladia* (Rodríguez-Prieto et al., 2007). Consequently it caused the necessity of the same transfer of *F. guiryi* to *Gloiocladia*. So a new nomenclatural combination for this species was proposed by me: *Gloiocladia guiryi* (Selivanova) Selivanova (2009).

Earlier one more taxon was described from western Bering Sea (Olytorskii Gulf, Lavrov Bay) and Glubokaya Bay (Selivanova & Zhigadlova, 2003). It represented the genus *Phycodrys* (Delesseriaceae, Rhodophyta) and was named *P. valentinae* Selivanova et Zhigadlova in honour of the well-known Russian phycologist Valentina F. Przhemenetskaya (Makienko) who has been studying marine algae of the Far Eastern seas of Russia for about 30 years. Later this species was also found by us in Avacha Gulf (Starichkov Island, south-eastern Kamchatka) (Selivanova and Zhigadlova, 2009).

The list of marine macroalgae of the Russian continental part of Bering Sea (without Commander Islands) totals to 153 species. Some of them were recorded by as as new for the Far Eastern seas of Russia (e.g. *Palmaria mollis* (Setchell et Gardner) Van der Meer et Bird, *Opuntiella californica* (Farlow) Kylin, *Membranoptera setchellii* Gardner (Selivanova, 2002).

The general list of algae of the western Bering Sea is presented below in the table format (Tables 1-3) for convenience of information retrieval and with the purposes of shortening printed space. Separate tables contain data on algae of 3 major groups of the colour spectrum corresponding to higher taxa: green (Division Chlorophyta), red (Division Rhodophyta) and brown (Division Ochrophyta, class Phaeophyceae).

It should be noted that taxonomic viewpoints of Russian and western phycologists may differ, and that is the case with interpretation of brown algae. According to the first viewpoint this taxon is treated as a class Phaeophyceae within the phylum Heterokontophyta, kingdom Chromista, empire Eukaryota (Guiry and Guiry, 2011). But we prefer to follow Russian concept of Belyakova et al. (2006) and to attribute the class Phaephyceae to the division Ochrophyta, kingdom Straminopila, empire Chromalveolata. Higher taxa (orders within divisions) are arranged in the tables according to their systematic position, while families within the orders, genera within the familes and species within the genera are given in alphabetic order. The list also contains information on the distribution of algae. Abbreviations in the column "Distribution within the studied area" correspond to the names of the areas shown on schematic map (Fig. 1). In addition to the abbreviations adopted in the legend to the figure Commander Islands are abbreviated in the tables as **CI.**

3.1 Species composition and distribution of brown algae in the studied area

On the total there are 44 species of brown algae found up to now on the shelf of the western part of Bering Sea and Commander Islands. The species list is given below in the table format (Table 1).

Record number	Taxon	Distribution within the studied area
	Order Desmarestiales	
	Family Desmarestiaceae	
1	*Desmarestia aculeata* (Linnaeus) Lamouroux	CI, K, O
2	*Desmarestia ligulata* (Lightfoot) Lamouroux	CI
3	*Desmarestia viridis* (O.F. Müller) Lamouroux	CI
	Order Ectocarpales	
	Family Pylaiellaceae	
4	*Pylaiella littoralis* (Linnaeus) Kjellman	CI, K,O, NR
	Family Chordariaceae	
5	*Chordaria chordaeformis* (Kjellman) Kawai et Kim	O, NR
6	*Chordaria flagelliformis* (O.F. Müller) C. Agardh	in all places
7	*Coilodesme bulligera* Strömfelt	CI
8	*Coilodesme californica* (Ruprecht) Kjellman	CI
9	*Delamarea attenuata* (Kjellm.) Rosenv	CI
10	*Dictyosiphon foeniculaceus* (Hudson) Greville	CI, K, O, NR
11	*Elachista tenuis* Yamada	CI
12	*Halothrix lumbricalis* (Kützing) Reinke	K, O
13	*Leathesia marina* (Lyngbye) Decaisne	CI
14	*Leptonematella fasciculata* (Reinke) Silva	CI, O
15	*Melanosiphon intestinalis* (Saund.) Wynne	K, O
16	*Punctaria plantaginea* (Roth) Greville	K, O
17	*Saundersella simplex* (Saunders) Kylin	OZ, K, O
18	*Stictyosiphon tortilis* (Ruprecht) Reinke	O
19	*Soranthera ulvoidea* Postels et Ruprecht	CI
20	*Streblonema scabiosum* Setchell et Gardner	CI
	Family Ectocarpaceae	
21	*Ectocarpus siliculosus* (Dillwyn) Lyngbye	CI, K, O
	Order Scytosiphonales	
	Family Scytosiphonaceae	
22	*Analipus filiformis* (Ruprecht) Papenfuss	K, O
23	*Analipus japonicus* (Harvey) Wynne	CI, K

24	***Petalonia fascia*** (O.F. Müller) Kuntze	**CI, K, O, NR**
25	***Scytosiphon dotyi*** Wynne	**CI, O**
26	***Scytosiphon lomentaria*** (Lyngb.) Link	**CI, K, O**
Order Laminariales		
Family Alariaceae		
27	***Alaria angusta*** Kjellman *emend*. Petrov	**CI, OZ, K, NR**
28	***Alaria marginata*** Postels et Ruprecht	**CI, K, O**
29	***Eualaria fistulosa*** (Postels et Ruprecht) Wynne	**CI, K**
Family Arthrothamnaceae		
30	***Arthrothamnus bifidus*** (Gmelin) Ruprecht	**OZ, K**
Family Chordaceae		
31	***Chorda asiatica*** Sasaki et Kawai	**K, O**
Family Costariaceae		
32	***Agarum clathratum*** Dumortier	**in all places**
33	***Thalassiophyllum clathrus*** (Gmelin) Postels et Ruprecht	**CI, K**
Family Laminariaceae		
34	***Cymathaere triplicata*** (Postels et Ruprecht) J.Agardh	**CI**
35	***Laminaria longipes*** Bory	**CI, OZ, K**
36	***Laminaria yezoensis*** Miyabe	**CI, OZ, K, O**
37	***Saccharina bongardiana*** (Postels et Ruprecht) Selivanova, Zhigadlova et G.I. Hansen	**In all places**
38	***Saccharina dentigera*** (Kjellman) Lane, Mayes, Druehl et Saunders	**CI, K**
39	***Saccharina gurjanovae*** (A. Zinova) Selivanova, Zhigadlova et G.I. Hansen	**OZ, K**
Order Fucales		
Family Fucaceae		
40	***Fucus evanescens*** C. Agardh	**In all places**
Order Ralfsiales		
Family Ralfsiaceae		
41	***Ralfsia fungiformis*** (Gunnerus) Setchell et Gardner	**CI, K, O**
42	***Ralfsia verrucosa*** (Areschoug) Areschoug	**K**
Order Sphacelariales		
Family Sphacelariaceae		
43	***Battersia arctica*** (Harvey) Draisma, Prud'homme et Kawai	**K, O**
44	***Chaetopteris plumosa*** (Lyngbye) Kützing	**K**

Table 1. Empire Chromalveolata Kingdom Straminopila Division Ochrophyta Class Phaeophyceae

3.2 Species composition and distribution of green algae in the studied area

Up now there are 36 species of green algae found on the shelf of the western part of Bering Sea and Commander Islands. The species list is given below in the table format (Table 2).

Record number	Taxon	Distribution within the studied area
	Class Bryopsidophyceae	
	Order Bryopsidales	
	Family Derbesiaceae	
1	***Derbesia marina*** (Lyngbye) Solier	**CI**
	Family Codiaceae	
2	***Codium ritteri*** Setchell et Gardner	**CI**
	Class Chlorophyceae	
	Order Chlorococcales	
	Family Chlorochytriaceae	
3	***Chlorochytrium inclusum*** Kjellman	**In all places**
	Family Endosphaeraceae	
4	***Codiolum gregarium*** Braun	**CI**
	Class Ulvophyceae	
	Order Cladophorales	
	Family Cladophoraceae	
5	***Chaetomorpha ligustica*** (Kützing) Kützing	**CI, K, O**
6	***Chaetomorpha linum*** (O.F. Müller) Kützing	**CI**
7	***Chaetomorpha melagonium*** (Weber et Mohr) Kützing	**OZ, K**
8	***Cladophora speciosa*** Sakai	**CI, K**
9	***Rhizoclonium riparium*** (Roth) Harvey	**CI, K, O**
	Order Ulotrichales	
	Family Gomontiaceae	
10	***Monostroma crassidermum*** Tokida	**K, O**
11	***Monostroma grevillei*** (Thuret) Wittrock	**CI, K, NR**
	Family Ulotrichaceae	
12	***Acrosiphonia duriuscula*** (Ruprecht) Yendo	**CI, K, O, NR**
13	***Psedothrix groenlandica*** (J.Agardh) Hanic et Lindstrom	**CI, O**
14	***Spongomorpha arcta*** (Dillwyn) Kützing	**CI**
15	***Spongomorpha mertensii*** (Yendo) Setchell et Gardner	**CI**
16	***Ulothrix flacca*** (Dillwyn) Thuret in Le Jolis	**CI, K, O**
17	***Ulothrix implexa*** (Kützing) Kützing	**O**
18	***Urospora penicilliformis*** (Roth) Areschoug	**CI, K, O**
19	***Urospora wormskjoldii*** (Mertens ex Horneman) Rosenvinge	**CI, O**
	Order Ulvales	
	Family Kornmanniaceae	
20	***Blidingia chadefaudii*** (Feldman) Bliding	**K**
21	***Blidingia minima*** (Nägeli ex Kützing) Kylin	**CI, K, O**
22	***Blidingia subsalsa*** (Kjellman) Kornman et Sahling	**CI, O**

23	***Kornmannia leptoderma*** (Kjellman) Bliding	**CI**
Family Ulvaceae		
24	***Percursaria percursa*** (C. Agardh) Rosenvinge	**CI, O**
25	***Ulva clathrata*** (Roth) C. Agardh	**K, O**
26	***Ulva fenestrata*** Postels et Ruprecht	**In all places**
27	***Ulva flexuosa*** Wulfen	**CI, K**
28	***Ulva linza*** Linnaeus	**CI, K, O**
29	***Ulva procera*** (Ahlner) Hayden, Blomster, Maggs, Silva, Stanhope et Waaland	**CI, O**
30	***Ulva prolifera*** O.F. Müller	**CI, K, O**
31	***Ulvaria splendens*** Ruprecht	**In all places**
Family Ulvellaceae		
32	***Acrochaete flustrae*** (Reinke) O'Kelly	**CI, O**
33	***Acrochaete geniculata*** (Gardner) O'Kelly	**CI**
34	***Acrochaete ramosa*** (Gardner) O'Kelly	**K**
35	***Acrochaete viridis*** (Reinke) R. Nielsen	**CI, K**
Class Trebouxiophyceae		
Order Prasiolales		
Family Prasiolaceae		
36	***Prasiola borealis*** Reed	**CI**

Table 2. Empire Eukaryota kingdom Plantae subkingdom Viridiplantae division Chlorophyta

3.3 Species composition and distribution of red algae in the studied area

On the total there are 129 species of red algae found up to now on the shelf of the western part of Bering Sea and Commander Islands. The species list is given below in the table format (Table 3).

Record number	Taxon	Distribution within the studied area
Class Compsopogonophyceae		
Order Erythropeltidales		
Family Erythrotrichiaceae		
1	***Erythrocladia irregularis*** Rosenvinge	**CI, K**
Class Bangiophyceae		
Order Bangiales		
Family Bangiaceae		
2	***Bangia fuscopurpurea*** (Dillwyn) Lyngbye	**CI**
3	***Porphyra abbottiae*** Krishnamurthy	**CI**
4	***Porphyra brumalis*** Mumford	**CI, O, NR**
5	***Porphyra gardneri*** (Smith et Hollenberg) Hawkes	**CI**
6	***Porphyra kurogii*** Lindstrom in Lindstrom et Cole	**CI, K, O, NR**
7	***Porphyra miniata*** (C. Agardh) C. Agardh	**CI, K, O, NR**
8	***Porphyra ochotensis*** Nagai	**CI**

9	***Porphyra pseudolinearis*** Ueda	**CI, K, O**
10	***Porphyra purpurea*** (Roth) C. Agardh	**CI, O, NR**
11	***Porphyra tasa*** (Yendo) Ueda	**O**
12	***Porphyra torta*** Krishnamurthy	**CI, NR**
13	***Porphyra variegata*** (Kjellman) Kjellman in Hus	**CI, K, O, NR**
	Class Florideophyceae	
	Order Hildenbrandiales	
	Family Hildenbrandiaceae	
14	***Hildenbrandia rubra*** (Sommerfelt) Meneghini	**CI, K, O**
	Order Corallinales	
	Family Corallinaceae	
15	***Bossiella frondescens*** (Postels et Ruprecht) Dawson	**CI**
16	***Corallina pilulifera*** Postels et Ruprecht	**CI, K,O**
17	***Pachyarthron cretaceum*** (Postels et Ruprecht) Manza	**CI, K**
	Family Hapalidiaceae	
18	***Clathromorphum circumscriptum*** (Strömfelt) Foslie	**CI, K,O, NR**
19	***Clathromorphum compactum*** (Kjellman) Foslie	**CI, K, O**
20	***Clathromorphum loculosum*** (Kjellman) Foslie	**CI, K, O**
21	***Clathromorphum nereostratum*** Lebednik	**CI, O**
22	***Clathromorphum reclinatum*** (Foslie) Adey	**CI**
23	***Phymatolithon lenormandii*** (Areschoug) Adey	**CI, OZ, K**
24	***Lithothamnion phymatodeum*** Foslie	**CI**
25	***Lithothamnion sonderi*** Hauck	**CI, OZ, K**
	Colaconematales	
	Colaconemataceae	
26	***Colaconema savianum*** (Meneghini) R. Nielsen	**O**
	Order Acrochaetiales	
	Family Acrochaetiaceae	
27	***Acrochaetium alariae*** (Jónsson) Bornet	**O**
28	***Acrochaetium arcuatum*** (Drew) Tseng	**OZ, K**
29	***Acrochaetium microscopicum*** (Nägeli ex Kützing) Nägeli	**K**
30	***Acrochaetium parvulum*** (Kylin) Hoyt	**K**
31	***Rhodochorton purpureum*** (Lightfoot) Rosenvinge	**CI, K**
	Order Palmariales	
	Family Meiodiscaceae	
32	***Meiodiscus spetsbergensis*** (Kjellman) Saunders et McLachlan	**O**
33	***Rubrointrusa membranacea*** (Magnus) Clayden et Saunders	**CI**
	Family Palmariaceae	
34	***Devaleraea compressa*** (Ruprecht) Selivanova et Kloczcova	**K, O, NR**
35	***Devaleraea microspora*** (Ruprecht) Selivanova et Kloczcova	**K, NR**

36	***Halosaccion firmum*** (Postels et Ruprecht) Kützing	**CI, K, O**
37	***Halosaccion glandiforme*** (Gmelin) Ruprecht	**CI, K, O, NR**
38	***Halosaccion minjaii*** I.K. Lee	**CI**
39	***Palmaria callophylloides*** Hawkes et Scagel	**CI, O**
40	***Palmaria hecatensis*** Hawkes	**CI, O**
41	***Palmaria marginicrassa*** I.K. Lee	**CI**
42	***Palmaria mollis*** (Setchell et Gardner) van der Meer et Bird	**CI, O, K**
43	***Palmaria stenogona*** (Perestenko) Perestenko	**CI, O, K**
Order Ahnfeltiales		
Family Ahnfeltiaceae		
44	***Ahnfeltia fastigiata*** (Endlicher) Makienko	**CI**
45	***Ahnfeltia plicata*** (Hudson) Fries	**CI, K**
Order Bonnemaisoniales		
Family Bonnemaisoniaceae		
46	***Pleuroblepharidella japonica*** (Okamura) Wynne	**CI**
Order Cryptonemiales		
Family Crossocarpaceae		
47	***Beringia castanea*** Perestenko	**CI**
48	***Cirrulicarpus gmelinii*** (Grunow) Tokida et Masaki	**CI**
49	***Cirrulicarpus ruprechtianum*** (Sinova) Perestenko	**CI, K, O, NR**
50	***Crossocarpus lamuticus*** Ruprecht	**CI, OZ, K**
51	***Hommersandia palmatifolia*** (Tokida) Perestenko	**CI, K, O**
52	***Kallymeniopsis lacera*** (Ruprecht) Perestenko	**In all places**
53	***Velatocarpus kurilensis*** Perestenko	**K, O**
54	***Velatocarpus pustulosus*** (Postels et Ruprecht) Perestenko	**CI, OZ, K, O**
Family Dumontiaceae		
55	***Constantinea rosa-marina*** (Gmelin) Postels et Ruprecht	**CI**
56	***Constantinea subulifera*** Setchell	**CI**
57	***Dilsea socialis*** (Postels et Ruprecht.) Perestenko	**OZ, K, O**
58	***Dumontia contorta*** (Gmelin) Ruprecht	**CI, K, O**
59	***Neodilsea natashae*** Lindstrom	**CI, K**
60	***Neodilsea yendoana*** Tokida	**CI, K, O**
Family Kallymeniaceae		
61	***Callophyllis radula*** Perestenko	**CI**
62	***Callophyllis rhynchocarpa*** Ruprecht	**CI, K, O**
63	***Euthora cristata*** (C. Agardh) J. Agardh	**In all places**
Order Halymeniales		
Family Halymeniaceae		
64	***Neoabbottiella araneosa*** (Perestenko) Lindstrom	**CI, OZ, K**
Order Gigartinales		
Family Cystocloniaceae		
65	***Fimbrifolium dichotomum*** (Lepechin) Hansen	**In all places**

66	*Rhodophyllis capillaris* Tokida	**CI, K**
Family Endocladiaceae		
67	*Gloiopeltis furcata* (Postels et Ruprecht) J. Agardh	**CI, K, O**
Family Furcellariaceae		
68	*Opuntiella californica* (Farlow) Kylin	**OZ, K**
69	*Opuntiella ornata* (Postels et Ruprecht) A. Zinova	**CI, OZ, K, O**
70	*Turnerella mertensiana* (Postels et Ruprecht) Schmitz	**In all places**
71	*Turnerella pennyi* (Harvey) Schmitz in Rosenvinge	**K**
Family Gigartinaceae		
72	*Mazzaella parksii* (Setchell et Gardner) Hughey, Silva et Hommersand	**CI, K**
73	*Mazzaella phyllocarpa* (Postels et Ruprecht) Perestenko	**CI, K, O**
Family Phyllophoraceae		
74	*Coccotylus truncatus* (Pallas) Wynne et Heine	**K, O**
75	*Lukinia dissecta* Perestenko	**CI**
76	*Mastocarpus pacificus* (Kjellman) Perestenko	**CI, K, O, NR**
77	*Mastocarpus papilatus* (C. Agardh) Kützing	**CI**
Order Nemastomatales		
Family Schizymeniaceae		
78	*Schizymenia pacifica* (Kylin) Kylin	**K, NR**
Order Rhodymeniales		
Family Faucheaceae		
79	*Gloiocladia guiryi* (Selivanova) Selivanova	**CI**
Family Rhodymeniaceae		
80	*Sparlingia pertusa* (Postels et Ruprecht) Saunders, Strachan et Kraft	**CI, K**
Order Ceramiales		
Family Ceramiaceae		
81	*Ceramium cimbricum* H. Petersen in Rosenvinge	**K**
82	*Ceramium deslongchampsii* Chauvin ex Duby	**K**
83	*Ceramium kondoi* Yendo	**CI, K, O**
84	*Microcladia borealis* Ruprecht	**CI**
85	*Scagelia breviarticulata* Perestenko	**CI**
86	*Scagelia pylaisaei* (Montagne) Wynne	**CI, K, O**
Family Delesseriaceae		
87	*Congregatocarpus kurilensis* (Ruprecht) Wynne	**CI**
88	*Hideophyllum yezoense* (Yamada et Tokida) A. Zinova	**CI, OZ, K, O**
89	*Hymenena ruthenica* (Postels et Ruprecht) A. Zinova	**CI, OZ, K, O**
90	*Laingia aleutica* Wynne	**CI**
91	*Membranoptera spinulosa* (Ruprecht) Kuntze	**In all places**
92	*Membranoptera serrata* (Postels et Ruprecht) A. Zinova	**K, NR**
93	*Membranoptera setchellii* Gardner	**OZ, K**
94	*Mikamiella ruprechtiana* (A. Zinova) Wynne	**CI**

95	***Nienburgia prolifera*** Wynne	**CI**
96	***Pantoneura fabriciana*** (Lyngbye) Wynne	**K**
97	***Pantoneura juergensii*** (J. Agardh) Kylin	**CI, OZ, K, NR**
98	***Phycodrys fimbriata*** (Kuntze) Kylin	**CI, OZ, O, NR**
99	***Phycodrys serratiloba*** (Ruprecht) A. Zinova	**CI, OZ, K, O**
100	***Phycodrys valentinae*** Selivanova et Zhigadlova	**O, NR**
101	***Phycodrys vinogradovae*** Perestenko et Gussarova in Perestenko	**CI**
102	***Tokidadendron bullata*** (Gardner) Wynne	**CI, O**
103	***Yendonia crassifolia*** (Ruprecht) Kylin	**CI, OZ, K, O**
Family Rhodomelaceae		
104	***Beringiella labiosa*** Wynne	**CI**
105	***Harveyella mirabilis*** (Reinsch) Schmitz et Reinke	**K, O**
106	***Neorhodomela larix*** (Turner) Masuda	**CI, K, O**
107	***Neorhodomela oregona*** (Doty) Masuda	**CI**
118	***Neosiphonia japonica*** (Harvey) M.S.Kim et I.K.Lee	**K**
109	***Odonthalia annae*** Perestenko	**CI**
110	***Odonthalia corymbifera*** (Gmelin) Greville	**CI**
111	***Odonthalia dentata*** (Linnaeus) Lyngbye	**CI, K, O, NR**
112	***Odonthalia floccosa*** (Esper) Falkenberg	**CI**
113	***Odonthalia kamtschatica*** (Ruprecht) J. Agardh	**CI, OZ, K, NR**
114	***Odonthalia ochotensis*** (Ruprecht) J. Agardh	**CI, K, O**
115	***Odonthalia setacea*** (Ruprecht) Perestenko	**CI, K, O**
116	***Polysiphonia morrowii*** Harvey	**CI**
117	***Polysiphonia stricta*** (Dillwyn) Greville	**CI, K, O**
118	***Pterosiphonia bipinnata*** (Postels et Ruprecht) Falkenberg	**In all places**
119	***Pterosiphonia hamata*** Sinova	**CI**
120	***Rhodomela pinnata*** Perestenko	**K, O**
121	***Rhodomela sibirica*** A. Zinova et Vinogradova in Vinogradova	**K, O**
122	***Rhodomela tenuissima*** (Ruprecht) Kjellman	**K, O**
123	***Tayloriella abyssalis*** Wynne	**CI**
Family Wrangeliaceae		
124	***Neoptilota asplenioides*** (Esper) Kylin	**CI, NR**
125	***Pleonosporium kobayashii*** Okamura	**CI**
126	***Pleonosporium vancouverianum*** (J. Agardh) Setchell et Gardner	**CI**
127	***Ptilota filicina*** J. Agardh	**CI, K, O, NR**
128	***Ptilota serrata*** Kützing	**In all places**
129	***Tokidaea serrata*** (Wynne) Lindstrom et Wynne	**CI**

Table 3. Empire Eukaryota Kingdom Plantae subKingdom Biliphyta Division Rhodophyta

In conclusion of this part I would like to point out that the studies on the species composition of any group of organisms are the basis for further scientific studies in biocenology, biogeography, ecology etc. As far as marine macrophytes are among the leading components of benthic communities of the shelf of Bering Sea their inventory is very important. In spite of the incompleteness of inventory works in this region main counters of the marine algal flora are already outlined and might serve as background of development of different scientific conceptions.

For instance knowledge on contemporary algal flora may be helpful for clarification of the problems of historical phytogeography, processes of the species formation and migration. It is also important for understanding of the regularities of forming and functioning of the ecosystems and the role of seaweeds in benthic communities. Shallow water zones of the shelf of the western part of Bering Sea and Commander Islands are also of interest for economic activity. Competent exploitation of their resources is possible only on the basis of reliable scientific data on the species composition, structure and distribution of benthic communities. These problems are discussed to some extent in the sections below.

4. Brief characteristics of the algal flora of the western part of Bering Sea and Commander Islands

In Russian phycological literature the whole water area of the Far Eastern Seas is considered to be divided into 7 large floristic regions: 1) the Sea of Japan, 2) small Kurile Islands region; 3) southern Kurile Islands region; 4) northern Kurile Islands region; 5) the Sea of Okhotsk; 6) Bering Sea; 7) Commander Islands (Perestenko, 1994). We carried out our studies in the last 2 regions and came to a conclusion that the Bering Sea region that according to Perestenko (1994) includes the whole Eastern Kamchatka coasts should be subdivided into 2 subregions practically equal in geographic extension and floristic significance: a) proper Bering Sea area in its geographic borders (from Bering Strait to Ozernoi Gulf) and b) south-eastern Kamchatka (from Kamchatskii Gulf to Lopatka Cape). The latter is out of the limits of the present study. Here we discuss marine algal flora of 2 major floristic complexes of the regions located in the upper part of North Pacific, those of Commander Islands and western continental coast of Bering Sea.

From the point of view of phytogeography both floristic complexes judging from the elements forming them may be attributed to boreal (cold-temperate) type (Table 4). The number of arctic-boreal and high-boreal species in the floristic complex of the Commander Islands totals to 41 %, in the floristic complex of western continental part of Bering Sea their number comes to 44 %. If so called wide-boreal elements are taken into account these figures increase correspondingly to 92% and 90 %.

Systematic analysis of the species list revealed that the largest orders in the floristic complex of the Commander Islands are: 1) within the divion Ochrophyta, class Phaeophyceae: Ectocarpales (contains 3 families, 11 genera and 12 species) and Laminariales (5 families, 7 genera and 10 species); 2) within the division Rhodophyta: Ceramiales (4 families, 24 genera and 38 species) and Cryptonemiales (in its traditional interpretation) (5 families, 13 genera and 17 species); 3) withihn the division Chlorophyta: Ulvales (3 families, 5 genera and 14 species). These orders include above 55 % of the total species number of the flora.

The situation on the western continental coast of Bering Sea is much the same, the largest orders in this floristic complex are: 1) within the division Ochrophyta, class Phaeophyceae: Ectocarpales (contains 3 families, 10 genera and 11 species) and Laminariales (5 families, 8 genera and 12 species); 2) within the division Rhodophyta: Ceramiales (4 families, 18 genera and 31 species) and Cryptonemiales (in its traditional interpretation) (5 families, 12 genera

Phytogeographic group	Commander Islands		Continental part of Bering Sea	
	Species number	%	Species number	%
Arctic-boreal	**17**	**10**	**24**	**16**
High boreal	**50**	**31**	**43**	**28**
Wide boreal	**83**	**51**	**70**	**46**
Boreal-tropical	**8**	**4**	**10**	**6**
Cosmopolitan	**6**	**4**	**6**	**4**
Total	**164**		**153**	

Table 4. Phytogeographic composition of the macrophytic algae floras of Bering Sea and Commander Islands

and 14 species); and 3) withihn the division Chlorophyta: Ulvales (3 families, 4 genera and 14 species). These orders include about 54 % of the total species number of the flora.

The largest higher taxon of the Commander Islands' flora is the division Rhodophyta consisting of 13 orders, 25 families, 63 genera and 103 species and exceeding the number of green and brown algae in sum (Phaeophyceae + Chlorophyta) in 1.7 times. Thus, the nucleus of the Islands' flora is represented by red algae. The largest genera within Rhodophyta, consisting of 5 and more species are as follows: *Porphyra* (10 species), *Odonthalia* (7 species), *Palmaria* (5 species) and *Clathromorphum* (5 species). The largest genus among Chlorophyta is *Ulva* (6 species), however Phaeophyceae has no genera with more than 3 species, though it contains the complex of genera *Laminaria*+ *Saccharina*, but even in this case the number of the species totals to only 4.

The division Rhodophyta is also the largest one in the flora of the western continental coasts of Bering Sea consisting of 14 orders, 25 families, 56 genera and 91 species and exceeding the total number of green and brown algae in 1.5 times. So the nucles of the Bering Sea flora is also formed by red algae though their number is less than that of Commander Islands (91 species versus 103 accordingly). The largest genus within Rhodophyta in the Bering Sea flora is *Porphyra* (8 species), other large genera containing 4 species each are: *Clathromorphum, Acrochaetium, Palmaria* and *Odonthalia*. The largest taxa among division Chlorophyta and class Phaeophyceae are correspondingly the genus *Ulva* (7 species) and the complex of genera *Laminaria*+ *Saccharina* (5 species).

The figures given above make it possible to outline main characteristics of the floras. Particularly, in accordance with data of systematic analysis in general marine algal flora of both regions can be characterized as variegated in the species composition and allochthonous by origin. It contains big number of monotypic genera and families. I mean those taxa of higher rank that are represented in the studied area by only one taxon of lower rank, i.e. a family represented by one genus and a genus represented by one species. On Commanders there are: 17 genera and 5 families in Phaeophyceae; 12 genera and 7 families in Chlorophyta; 42 genera and 9 families in Rhodophyta; in Bering Sea: 18 genera and 7 families in Phaeophyceae; 7 genera and 5 families in Chlorophyta; 35 genera and 11 families in Rhodophyta. Allochthonous type of the flora is also confirmed by relatively low ratios: species/genus (1.6 for both regions); species/family (3.6 for Commander Islands and 3.4 for Bering Sea) and genus/family (2.3 for Commander Islands and 2.1 for Bering Sea). No endemic species were found. Variegated species composition shows that both floristic complexes are under strong influence of adjacent areas. Main ecologic factors of the existence of contemporary floras of algae-macrophytes in the area are formed by ocean currents.

The Bering Sea marine algal flora presumably (on the assumption of paleonthologically verified data on the other groups of organisms) was formed mostly by low-boreal elements that adapted to fall of temperature in Cainozoic period. At present this flora is being enriched due to the penetration of high-boreal and arctic species (e.g. *Dilsea socialis*, *Rhodomela sibirica*) via cold-water Eastern Kamchatka current. This current goes further to the south and in such a way cold-water species are spread along the south-eastern Kamchatka coasts (up to Lopatka Cape) (Fig. 1). Thus the marine algal flora of Bering Sea has a well-defined migratory character and is under strong influence of the Arctic area.

On the other hand Commander Islands are greatly influenced by American continent due to the branch of Alaska current providing penetration of American elements of flora. I suppose this process to be main tendency of the Islands' flora development. As a result of invasion of American elements marine algal flora of the Commander Islands is more rich and diverse as compared to other areas of Bering Sea. For example, elementary analysis of the data from our Tables 1-3 show that there are 57 species of marine macrophytes (9 species of green, 10 – of brown and 38 - of red algae) that are met only on Commander Islands and are not found on the continental coast of Bering Sea. Many of these species were described from the American Pacific coasts (e.g. *Streblonema scabiosum, Acrochaete geniculata, Erythrocladia irregularis, Palmaria callophylloides, P. hecatensis, Laingia aleutica, Nienburgia prolifera, Beringiella labiosa, Tayloriella abyssalis*). Of course, absence of records of some species from the continental part of Bering Sea does not in all cases mean that these algae do not grow there, possibly it is due to less careful studies in this area in contrast to Commander Islands.

It should be noted that in spite of the fact that all above-mentioned species were described from the American continent they are not necessarily American in their origin. It is quite possible that marine algal flora of the American continent is just more comprehensively studied and new species are found and described there more often in comparison with the Russian Pacific sector. And it is no wonder, because big and well-equipped groups of phycologists from Canada and USA effectively work in their sector of the Pacific Ocean while in Russia in fact only small isolated groups of enthusiasts try to study marine algae of the western Pacific coasts. In any case the presence of the species on Commander Islands that are not met in other areas of the Russian Pacific but are common with American coast (*Coilodesme californica*, *Pleonosporium vancouverianum*, *Microcladia borealis*, *Tokidaea serrata, Nienburgia prolifera, Laingia aleutica, Beringiella labiosa, Odonthalia floccosa* etc.) brings together their flora with the floras of Aleutian Islands and Alaska. So Commander Islands serve as a peculiar bridge uniting American and Asian algal floras.

Comparison of the species composition of the macrophytes of the Commander Islands' shelf and that of the south-eastern Kamchatka reveals certain similarity of the floras of these two regions (Jaccard's coefficient of community K_j = 0.68) and testify to belonging of the Commander Islands flora to Asian type.[1] According to my calculations similarity between

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[1] The geological data are also in favour of hypothesis of Asian origin of marine algal flora of the Commander Islands. In accordance with the theory of continental drift the Pacific islands (together with their underwater foundations) are considered to be the edge chains separated from the continental blocks. During general movement of the Earth crust along the mantle oriented mostly to the west they lagged behind and remained in the east. So their original position was closer to the Asian continent in comparison with the present day (Vegener, 1984). In some sense hypothesis of Asian origin of the Commander Islands marine algal flora is confirmed by data on terrestrial flora of some well studied

the floras of south-eastern Kamchatka and western part of Bering Sea is a little less (K_j = 0.63), and it is the least between the floras of the Commander Islands and western continental coast of Bering Sea (K_j = 0.51). I explain phenomenon of such low similarity (in other words, considerable difference) between floristic complexes of geographically close water areas by peculiarities of the system of ocean currents in this sector of the North Pacific, existence of already mentioned Eastern Kamchatka and Alaska currents (Fig. 1) providing favourable conditions for penetration of invasive species of different origin from the adjacent areas, namely from the Arctic into northern part of Bering Sea and from the American continent to Commander Islands. To tell the truth, such deviations in comparative floristic coefficients may happen due to purely statictical reasons (Kafanov et al., 2004). Nevertheless my conclusions are in agreement with the data of K.L. Vinogradova & L.P. Perestenko (1978) who also showed considerable difference of marine flora of the western Bering Sea from those of the south-eastern Kamchatka and Commander Islands.

5. The problem of diversity conservation of algae in the western Bering Sea including Commander Islands

Conservation of biodiversity is a primary condition for stability of biosphere. Studies on biodiversity became a component part of National strategy of Russia more that 10 years ago. Creation of the system of the specially protected nature areas (SPNA-s) serves as the most important instrument of biodiversity conservation in our country. At present 9 SPNA-s with marine coastal area aimed at conservation of hydrobionts diversity have been created in the studied sector of the North Pacific. The northernmost of these areas – Nature Park "Beringia" is located within administrative borders of Chukchi Autinomous District and is just mentioned but not included in our discussion.

5.1 Commander State Biosphere Reserve

Commander State Biosphere Reserve is the most important among the rest 8 SPNA-s. It embraces practically the whole archipelago Commander Islands (Fig. 1). Necessity of protection of the unique biodiversity of Commander Islands was acknowledged in Russia many years ago.

In 1958 the Soviet government prohibited fishery and other economic activity in 30-miles sea area around the Islands with the purpose of conservation of marine mammals (sea otters, fur seals). In 1993 in accordance with Decision of the government of the Russian Federation the state biosphere "Komandorskii" (Commander) reserve with the area of 3648679 hectares was established, its coastal area covering 3463300 hectares. This is one of the largest reserves in the world and taking into account the size of its coastal zone it could be considered as a marine reserve. Main objectives of this state biosphere reserve are: studies and protection of the unique natural complexes of the archipelago, genofond of plants and animals, protection of large rookeries of marine mammals, population of blue fox, nesting spots of rare birds and also conservation of historical traces of Vitus Bering's expedition. Besides that Commander Islands are the place of compact residence

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Pacific islands and archipelagos. For instance, aboriginal flora of Hawaiian Islands (without agricultural and invasive species) is more allied with the flora of the Old World than with that of their nearest neighbour – North America (Drude, 1890).

of indigenous small people of the North – Aleutians with their traditional mode of life and culture that also need protection. Based on these grounds the Commander Reserve was included in the worldwide net of the biosphere reservations in the frames of the UNESCO program "The man and the biosphere" (MAB).

Organization of the state reserve helps to take under protection all marine organisms inhabiting the Islands, including marine macrophytic algae. And this fact inspires optimism because the majority of rare species included in the Red Data Books of Kamchatka and Russia grow on Commander Islands. In most cases the Islands are the only area of their inhabitance within the Russian coasts (Selivanova, 2007). Conservation of these species in the nature has not only scientific importance but is an integral part of conservation of biodiversity of the coastal zone in its broad sense (i.e. not only of the species diversity but also diversity and stability of marine ecosystems).

It is expedient to note that all species included in the Red Data Book of Kamchatka are rare because of natural reasons, their number is not reduced by human activity and their conservation needs rather non-interference in natural habitats than any active measures of protection. However it is necessary to exclude anthropogenic pollution of the coastal area and poaching in the Reserve's water area. Of course, rare algae themselves cannot be the objects of harvesting but irrational catch of other hydrobionts may cause nonreversible changes in marine ecosystems and as a result – extermination of rare species of algae. In fact there are groups of algae growing on Commander Islands that should be attributed to the category of so called vulnerable species and these are commercial laminarian species (*Laminaria*, *Saccharina*). At present they are abundant on the Islands and there are no real threats for decrease in their diversity. In my opinion remoteness of the Islands, small number of their human population and relatively low demand for the plant marine products will prevent local community from poach harvest of seaweeds as it happened in the vicinity of Petropavlovsk-Kamchatskii. However there is a risk of their overharvest in case of large-scale uncontrolled commercial catch. I think that this perspective should be treated as a possible threat for the biodiversity conservation on the shelf of the Commander Islands.

5.2 Reserve "Karaginskii Island"

Reserve "Karaginskii Island" is another important SPNA in the Bering Sea that covers Karaginskii Island located in Karaginskii Gulf and separated from Kamchatka Peninsula by Litke Strait (Fig. 1(2). At organization of the Reserve "Karaginskii Island" in 1996 all types of commercial catch were prohibited in the water areas around the Island. It was supposed to organize here marine biosphere reserve in succeeding years but the program did not receive financial support. At present Reserve "Karaginskii Island" does not exist any more however the Island is included in the list of wetlands in accordance with Ramsar Convention. There still remains possibility of getting support for the program of organization of marine biosphere reserve on Karaginskii Island, we consider it very expedient because of high biodiversity of marine flora and fauna of the area that needs protection.

Besides the above-mentioned SPNA-s there are areas within Bering Sea with different nature protective status aimed at conservation of marine ecosystems:

5.3 State nature reserve of federal significance "Koryakskii"

State nature reserve of federal significance "Koryakskii" was founded in 1995 by the Decision of the government of the Russian Federation. The reserve covers a part of Goven

Peninsula and adjacent water area of Lavrov Bay (Olyutorskii Gulf) (Fig. 1 (3). The protected water area totals to 83000 hectares. The purpose of creation of the "Koryakskii" Reserve was to provide protection of the whole ecosystem complex of the northern Kamchatka including marine and coastal ecosystems of Bering Sea with large colonies of sea birds.

5.4 Nature park "Beringia"

Nature park "Beringia", founded in 1992, is located in Chukchi Autunomous District and includes a part of Bering Sea water area (Fig. 1 (4).

In addition there are five **Nature Monuments of regional significance** that have protected marine area within their borders: «**Verkhoturov Island**», «**Witgenstein Cape**», «**Witgenstein Rock**», «**Yuzhnaya Glubokaya Bay**» and «**Anastasia Bay**». It is planned to crerate some new marine nature parks and state nature reserves of federal significance. However all already existing SPNA-s with the exception of Commander State Biosphere Reserve are just nominal organizations without real system of nature protection service. As far as the level of knowledge on their biodiversity is concerned it is extremely low and scientific studies seem to us to be the major task for future.

However it should not preclude the possibility of seaweed harvest on the territory of SPNA-s even with high nature protective rank. For instance, Commander Reserve is thought to be perspective for plant resources exploitation in the areas with permitted economic activity (Selivanova, 2008b). It is necessary to elaborate well-grounded recommendations on permissible level of harvest that in its turn should be based on reliable estimate of algal resources. Correct estimation of resources is important for proper decisions on biodiversity conservation not destroying ecosystem integrity and providing restoration of natural seaweed resources.

6. Preliminary data on seaweed resources of the Russian sector of North Pacific

The largest and most productive algal communities in the Russian sector of North Pacific (western continental part of Bering Sea and Commander Islands) are formed by seaweeds of the order Laminariales. These algae are main objects of commercial harvest. Unfortunately there are no exact present-day quantitative data on seaweed resources in the studied area. The only information available is just preliminary, fragmentary and rather old, dated to the first dacades of the last century (Kongisser, 1933; Gail, 1936). Naturally we need more up-dated information concerning this matter but practical estimation works require considareble expeditionary expenses, equipment and efforts of many specialists. At present it is unreal to expect that these works will be carried out. So the only way out is to make calculations using so called expert method. It is a theoretical estimation based on remote sensing data on the bottom area suitable for the growth of seaweeds and their projective cover in communities. In accordance with this expert estimation general stock of seaweeds resources in the Russian sector of North Pacific comes to 10 million tons.

In spite of such rich stock there is a risk of overharvest in case of poor organization of catch. Exceeding press on commercial algae may cause abrupt decrease of their number and futher replacement by competitive species, for example, by crustose coralline algae. This may cause irreversible changes in the structure of plant benthic communities and as a result total loss of commercial species. That is why scientific recommendations on permissible level of harvest are very important.

In my opinion the most prespective region for sustainable use of seaweed resources is a shallow water area of Commander Islands in spite of the fact that their major part is included in the state biosphere reserve. The reasons for such statement are as follows: 1) this region is one of the most pristine in the Far Eastern seas of Russia, seaweeds growing there are suitable for food and pharmaceutical use not only by the local population but also for export; 2) analysis of the benthic communities of the Islands reveal that their state is good enough and the number of laminarian algae is actually excessive; 3) it will be expedient and even necessary to organize harvesting of commercial algae in the zones of permitted economic activity; 4) in the latest few years the scheme of initial zonation of the Reserve was reconsidered and the limits of economic zones were appreciably extended.

However as it was already said, competent exploitation of seaweed resourses should be based on reliable research data on the algal species composition, number and distribution within the area. This information is obviously insufficient and additional studies are necessary.

We have at our disposal only relatively old data on the stock and distribution of the laminarian algae on Commander Islands obtained during expeditions of Kamchatka Branch of the Pacific Institute of Geography in 1986, 1989-1991. In accordance with these data *Saccharina bongardiana* forms relatively small areas (20-30 hectares) covered by kelp at the depths of 1-2 meters. In sheltered bays *S. bongardiana* is met up to the depth of 12 m, forming mixed communities with other brown algae. Mean biomass of *S. bongardiana* varied in different years. The area covered by the kelp with the dominance of this species did not exceed 10 km^2, total stock came to a 1-1.5 thousand tons. In exposed habitats *S. bongardiana* was replaced by a competitive species *S. dentigera.*

S. dentigera formed a distinct belt aroung the coast of Bering Island at the depths from 3 to 10 m. Some patches are met from the depth of 0 (in exposed to waves places) to 25 m. Plants often settled on coralline alga *Clathromorphum nereostratum* and obtaining big size were cast ashore by storms together with coralline crusts on haptera. The portion of *S.dentigera* in cast ashore mass reached 70%. The biomass of *S. dentigera* varied in different years in 3-4 times. The area occupied by the kelp of this species came to 200 km^2, and the stock averaged to 2 million tons.

At present only algae of the genera *Saccharina* and *Laminaria* are the objects of harvest in Kamchatka Region though other laminarian algae (*Alaria, Eualaria*) are also suitable for food, forage and technological use. In particular a giant alga *Eualaria fistulosa* that forms dense population around Bering Island at the depths 5-15 m may be treated as a perspective commercial species. Sometimes it is met in deeper places (up to 25 m) and vice versa rises to 1-2 m in sheltered habitats. The density of populations of *E. fistulosa* varied up to 10 times from a year to year (from 0.6 to 7 kg/m^2). Kelp formed by this alga occupied the area of about 100 km^2. Floating plants of *E. fistulosa* and their parts formed rather thick fields with projective cover up to 60%. In autumn-winter period these floating fields of *E. fistulosa* were destroyed by storms but in April-May they appeared again and reached their maximal size (10-12 m) by June-July due to the fast growth of attached algae. The stock of this alga on Bering Island was estimated at its minimal amount in 1992 to be 82 thousand tons and at its maximal amount in 1990-1991 – up to 700 thousand tons. The total amount of *E. fistulosa* at both Bering and Medny Island in 1990-es averaged to 925 thousand tons.

As is well known abundance of brown algae is subjected to unpredictable changes as a result of harvesting, so their natural fluctuations should be taken into account because harvesting in unfavourable for seaweeds years may lead to abrupt decrease in their stock.

Three species we discuss (*S. bongardiana, S. dentigera* and *E. fistulosa*) have different growth peculiarities, reproduction and demographic structure of the populations, so the strategy of their harvest should be different.

For instance, *S. bongardiana* may be harvested in the volumes of 50 % of its stock in each area (for Bering Island 0.5-0.75 thousand tons). The most expedient way of this species harvesting is cutting of algae in the intertidal zone during low tides using special knife (pruner) in 20 cm above the meristem zone at basal part of the blade. This provides fast re-growth of the blade and makes it possible to get aftercrop in 1.5-2 months, i.e. to carry out multiple harvesting during a vegetation period.

On the other hand the total harvest volume of *S. dentigera* should not exceed 30 % of the total stock because algae of this species grow much slower than *S. bongardiana* but have longer lifetime (presumably, 4-5 years of *S. dentigera* versus 2-3 years of *S. bongardiana*). Inasmuch as *S. dentigera* grows at considerable depths and constitutes a major part in cast ashore algae, collection of fresh samples of *S. dentigera* from the stormy beached seaweed mass seems to be the most rational method of its harvesting.

Harvesting of *E. fistulosa* is possible from the boat by wrapping floating parts of the plants round long hook (kanza). For the sake of fast restoration of the stock it is expedient to cut them at the depth less than 1 m from water surface. Owing to high growth rate of the fronds of *E. fistulosa* it is possible to harvest phytomass several times during one vegetation season. Plants are able to reproduct successfully because the lower parts with sporophylles are not damaged. Annual estimated yield of *E. fistulosa* for Bering Island comes to 120 thousand tons.

It should be accentuated that the use of dragrope is inadmissible in seaweed harvest as it causes considerable loss of raw material, damage of substratum, death of juvenile plants and as a result – elimination of thickets of algae. Moreover torn off plants sink and form dead bottom sediments, in the process of decay they reduce hydrogene contents in the near-bottom water layers.

Recommended by us methods of brown algae harvesting at the coasts of Commander Islands satisfy the international requirements of exploitation of seaweed resources and do not conflict with the nature protection regime in the region. They are ecologically justified because produce no negative effects on the benthic marine ecosystems and populations of marine mammals. It is necessary to take into account the depths of algal vegetation and water temperature in order to fix optimal period of harvest in each specific area. According to our data the most favourable time of seaweed harvest on Bering Island is May-June. Plants growing in shallow water areas develop more rapidly and start reproduction earlier owing to faster water warming-up than algae growing in deeper areas. That is why first of all seaweeds from shallow water zones should be harvested. According to my calculations in the intertidal zone of Commander Islands it is possible to get 3-5 kg from m^2 and in the upper sublittotal zone – up to 10-12 kg of raw seaweeds.

As far as the continental part of Bering Sea is concerned the present-day information on its seaweed resources is practically absent. That is why I would like to withhold recommendations on organization of harvest in this area. Commercial catch of seaweeds without scientific grounds at contemporary technological approach may cause irreplaceable losses of seaweeds and even destruction of the benthic communities. I think that studies on biodiversity of the western part of Bering Sea and ensuring of effective work of SPNA-s should precede organization of seaweed harvesting in the area.

7. Conclusion

Inventory of marine flora of the Russian sector of North Pacific is necessary not only for clarification of scientific problems of phycology but also for solving of some important practical problems. In particular, there is a threat of decrease of biodiversity of the region and loss of the still unknown species. Already known rare species included in the Red Data Book of Kamchatka (Selivanova, 2007) are also under the threat of loss. So I consider it very important to continue studies on biodiversity of marine coastal ecosystems of Bering Sea paying special attention to their plant components that form basic environments for valuable commercial objects (herring, rock trout, sea urchins etc.). In order to prevent their loss or decrease of number it is necessary to organize valid protection of resources of the shelf of the area. I am confident that sustainable harvest will make it possible to avoid destruction of marine ecosystem integrity and provide restoration of natural seaweed resources and their long-term exploitation. This will help to supply population of Kamchatka Region with this valuable food and technological natural raw material and organize its export to other areas of Russia and abroad.

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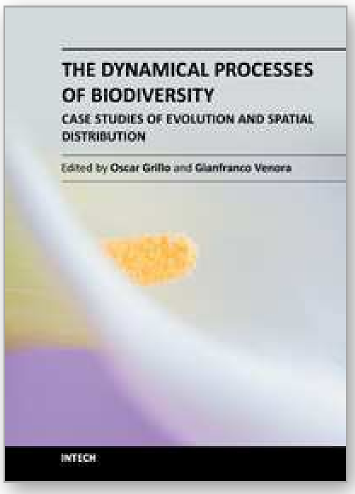

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