Asian Fisheries Science **24** (2011):397-412

ISSN 0116-6514
E-ISSN: 2073-3720
https://doi.org/10.33997/j.afs.2011.24.4.005

Some Approaches to Reducing Non-commercial Bycatch of Bottom Trawl Fisheries in the Western Bering Sea

A.M. ORLOV[*]

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO)
17, V. Krasnoselskaya, Moscow, 107140, Russia

Abstract

This paper reports on a study of trawl bycatch in the western Bering Sea based on catch data obtained from nine bottom trawl surveys (a total 365 bottom trawl stations) and commercial fishing operations (a total 980 bottom trawl hauls) between 1995 and 1998. Minimum catch rates of non-commercial bycatch were registered west of 170°E and east of 180°while maximum catch rates were observed between 171-172°E, 173-175°E and 177-178°E. Minimum bycatch rates were observed at depths of less than 150 m while the proportion of non-commercial bycatch increased with depth and reached its maximum value at depths over 650 m. The maximum bycatch rates were observed in May and November and minimums were observed in December. The maximum bycatch rates were registered from 13:00 to 18:00. Minimum proportions of bycatch occurred between 19:00 and 24:00. Among the bycatch species, grenadiers may be used for canned liver and eggs and their flesh may be processed to human or animal food and probably to surimi. Skate wings are suitable for human consumption. Sculpins and eelpouts are suitable for processing to canned fish or human food. The remainder of the non-commercial bycatch species except for snailfishes may be processed to fish powder.

Introduction

The term bycatch commonly refers to that part of the catch that is not composed of the desirable individuals of the target species. Bycatch includes those fish captured that are undersized individuals of the target species, prohibited or inedible species or those unsalable. Different parts of the bycatch are sometimes called trash, discard and incidental catch. Global estimates of discarded fish ranged from 7.3 to 39.5 million tonnes per year, constituting roughly from 8% to one-third of the total marine catch (Alverson, 1996, 1997; Kelleher, 2005). Bycatch is a world economic, environmental, and political problem (Alverson and Hughes, 1996; Alverson, 1999; Hall et al. 2000).

Bycatch problems attracted the attention of society as demonstrated by the number of specific meetings organized by national and international governmental and non-governmental organizations (Dewees and Ueber, 1990; Schoning et al. 1992; Alverson et al. 1994; Baxter and Keller, 1996, 1997; Grainger, 1997; Alverson, 1996, 1997; Malchoff, 1999).

---

[*]Corresponding author. E-mail address: orlov@vniro.ru

This paper was presented at the ICES symposium on "Fishing Technology in the 21st Century" (Boston, USA , 30 October - 3 November 2006).

The problem of reducing bycatch began to be addressed relatively recently, though most of this work has to do with the improvement of fishing gear and development of bycatch reduction devices (Perra, 1992; Hickey et al. 1993; Kennely and Broadhurst, 1998; Broadhurst et al. 2002; Fonteyne and Polet, 2002; Davis, 2002). Only a few recently published papers deal with the more complete utilization of the species caught incidentally by way of developing processing techniques (Feidi, 1989; Clucas, 1999; Isaac and Braga, 1999). Other biological and behavioral aspects of the problem have been examined to a lesser extent (Adlerstein and Trumble, 1993; Anderson and Clark, 2002; Walker et al. 2002).

Although our knowledge of discards in world fisheries has increased rapidly in the past two decades, quality and detailed information is still lacking for many regions of the world (Alverson, 1996). The highest quantities of discards are from the northwestern Pacific and the largest bycatches occur in groundfish trawl and shrimp trawl fisheries (Alverson, 1997; Kelleher, 2005). Until recently bycatch studies of bottom trawl fisheries of the northwestern Pacific were scarce. In Russian waters of the Far East seas such investigations are at the initial stage only (Vinnikov and Terentiev, 1999; Ermakov, 2002; Ermakov and Karyakin, 2003; Ermakov and Badayev, 2005; Terentiev and Vasilets, 2005; Orlov, 2008).

This paper is based on the author’s own study and provides some possible approaches to the solution of bycatch reduction problem by the example of multispecies bottom trawl fishery in the western Bering Sea, the northwestern Pacific Ocean, Russia. The objectives of this study are to optimize the areas, depths, seasons and time of fishing in terms of minimizing the non-commercial bycatch and to identify prospective fishing species which are not being utilized at present, and to specify procedures for their processing.

Materials and Methods

This paper is based on catch data obtained from nine bottom trawl surveys (a total 365 bottom trawl stations) and commercial fishing operations (a total 980 bottom trawl hauls) between 1995 and 1998 conducted in the western Bering Sea. The total area investigated was between 59°14´N and 61°01´N and between 166°19´E and 178°29´W (Fig. 1). Catch data were obtained from three chartered commercial Japanese trawlers (Tenyumaru 57, Tenyumaru 78 and Kayomaru 28). Fishing was conducted 24 hr a day at depths between 111-675 m. Commercial types of polyethylene bottom trawl nets with 100 mm mesh size in cod-end were used. The trawl mouth, 25-30 m wide and 5-7 m high, was rigged with a steel and rubber ball roller; the mean trawl speed was 3.6 knots. In this study, only samples from successful trawls were used for analysis. This meant that the horizontal and vertical dimensions of the trawl mouth were within the normal range, the roller was constantly in contact with the bottom, the net suffered little or no damage during the tow, and no derelict fishing gear was encountered. Most trawls were made along isobaths. Trawls in which the depth varied considerably were excluded from the analysis. Since the duration of the hauls varied notably (0.5-1.0 hr during bottom trawl surveys and up to 19 hr, usually 9-11 hr during commercial fishing operations), all catches were subsequently adjusted for trawl time and catch rates calculated for standard 1 hr hauls. During the bottom trawl surveys the whole catch was analyzed. During commercial fishing operations, representative random sub-samples were taken from each trawl catch. These sub-samples were taken from different parts of the catch for analysis (2-3 baskets were selected from the conveyer belt at the beginning, middle, and the end of catch processing), and sorted by species; subsequently individuals were counted and weighed. The rest of the catch was examined on the conveyer belt to identify species not found in random sub-samples. The results were extrapolated to the total catch. Catch and bycatch were recorded and species identification was made by scientists of various research institutes that took part in the joint research program. Three categories of fish catch were designated, namely: commercially important species (target species and commercial bycatch), prospective unmarketable species (species that are presently not marketed but that may have future potential) and non-commercial bycatch species. For each category, the percentage of the total catch weight was calculated. Those data were used for further analysis. To detect fine local differences in catch composition, the study area was divided into sections spanning 1° in longitude and encompassing the full inshore-offshore extent of the fishery within each 1° section. Data on appropriateness of currently unmarketable species for direct consumption and processing in human, pet and animal food were obtained from published and internet sources, observations aboard Russian and Japanese trawlers, conversations with some fisheries managers, and observations in Japanese fish restaurants.

Fig. 1. Locations of bottom trawl stations in the western Bering Sea, 1995-1998 (thin lines show 500 and 1000 m isobaths).

Results and Discussion

The waters of the western Bering Sea feature a great diversity of species. From the Russian waters of the western Bering Sea, 318 fish species are known (Parin, 2004). In the present study, about 90 groundfish species were recorded in bottom trawl catches, of which 19 are of commercial importance (Table 1). By weight, these species comprised 69.1% of the total bottom trawl catch (Fig. 2). Five species are objects of specialized bottom trawl fisheries, namely walleye Pollock (*Theragra chalcogramma),* Pacific cod (*Gadus macrocephalus),* Pacific halibut(*Hippoglossus stenolepis),* Pacific black halibut (*Reinhardtius hippoglossoides* *matsuurae)*, and red squid (*Berryteuthis magister)*. Other, non-target species were considered in four categories, namely deepsea fishes, commercial bycatch, prospective species, and non-commercial bycatch. The species complex of a specialized deepwater fishery comprises at least eight species: shortraker rockfish (*Sebastes borealis),* blackspotted rockfish (*S. melanostictus),* broadbanded thornyhead (*Sebastolobus macrochir),* shortspine thornyhead (*S. alascanus),* Kamchatka flounder (*Atheresthes evermanni),* arrowtooth flounder (*A. stomias),* sablefish (*Anoplopoma fimbria),* and roughscale sole (*Clidoderma asperrimum)*. Some species caught in small quantities constitute commercially marketable bycatch that includes at least seven species: Pacific ocean perch (*Sebastes alutus),* Pacific herring (*Clupea pallasii),* Atka mackerel (*Pleurogrammus monopterygius),* rex sole (*Glyptocephalus zachirus),* flathead sole (*Hippoglossoides elassodon),* northern rock sole (*Lepidopsetta polyxystra),* and Alaska plaice (*Pleuronectes quadrituberculatus).* Species that are presently virtually unutilized but that have prospects for use comprise about 27% of the catch weight. These species are Pacific sleeper shark (*Somniosus pacificus),* softnose skates (Arhynchobatidae), grenadiers (Macrouridae), eelpouts (Zoarcidae), large sculpins (Cottidae), prowfish (*Zaprora silenus),* and large poachers (Agonidae). About 1.5% of the catches that came from the study area are non-commercial species. These are snailfishes (Liparidae), small sculpins (Cottidae), soft sculpins (Psychrolutidae), small poachers (Agonidae), lumpsuckers (Cyclopteridae) and some other species.

Table 1. Composition of catches (% by weight) during bottom trawl surveys and commercial fishing operations in the western Bering Sea, 1995-1998.

Common name	Scientific name	Proportion of catch, %
Target Species		
Walleye pollock	*Theragra chalcogramma*	31.2
Pacific cod	*Gadus macrocephalus*	2.5
Pacific halibut	*Hippoglossus stenolepis*	5.5
Pacific black halibut	*Reinhardtius hippoglossoides matsuurae*	5.5
Red squid	*Berryteuthis magister*	15.8
Deep Sea Fishes		
Shortraker rockfish	*Sebastes borealis*	8.6
Blackspotted rockfish	*S. melanostictus*	
Broadbandedthornyhead	*Sebastolobus macrochir*	
Shortspinethornyhead	*S. alascanus*	
Kamchatka flounder	*Atheresthes evermanni*	
Arrowtooth flounder	*A. stomias*	
Sablefish	*Anoplopoma fimbria*	
Roughscale sole	*Clidoderma asperrimum*	
Commercial Bycatch		
Pacific ocean perch	*Sebastes alutus*	2.8
Pacific herring	*Clupea pallasii*	
Atka mackerel	*Pleurogrammus monopterygius*	
Rex sole	*Glyptocephalus zachirus*	
Flathead sole	*Hippoglossoides elassodon*	
Northern rock sole	*Lepidopsetta polyxystra*	
Alaska plaice	*Pleuronectes quadrituberculatus*	
Prospective Species		
Pacific sleeper shark	*Somniosus pacificus*	26.8
Deepwater skates	Arhynchobatidae	
Grenadiers	Macrouridae	

Table 1. *(contd.)*

Eelpouts	Zoarcidae	
Large sculpins	Cottidae	
Prowfish	*Zaprora silenus*	
Large poachers	Agonidae	
Non-Commercial Bycatch		
Snailfishes	Liparidae	1.4
Lumpsuckers	Cyclopteridae	
Soft sculpins	Psychrolutidae	
Small sculpins	Cottidae	
Pricklebacks	Stichaeidae	
Small poachers	Agonidae	

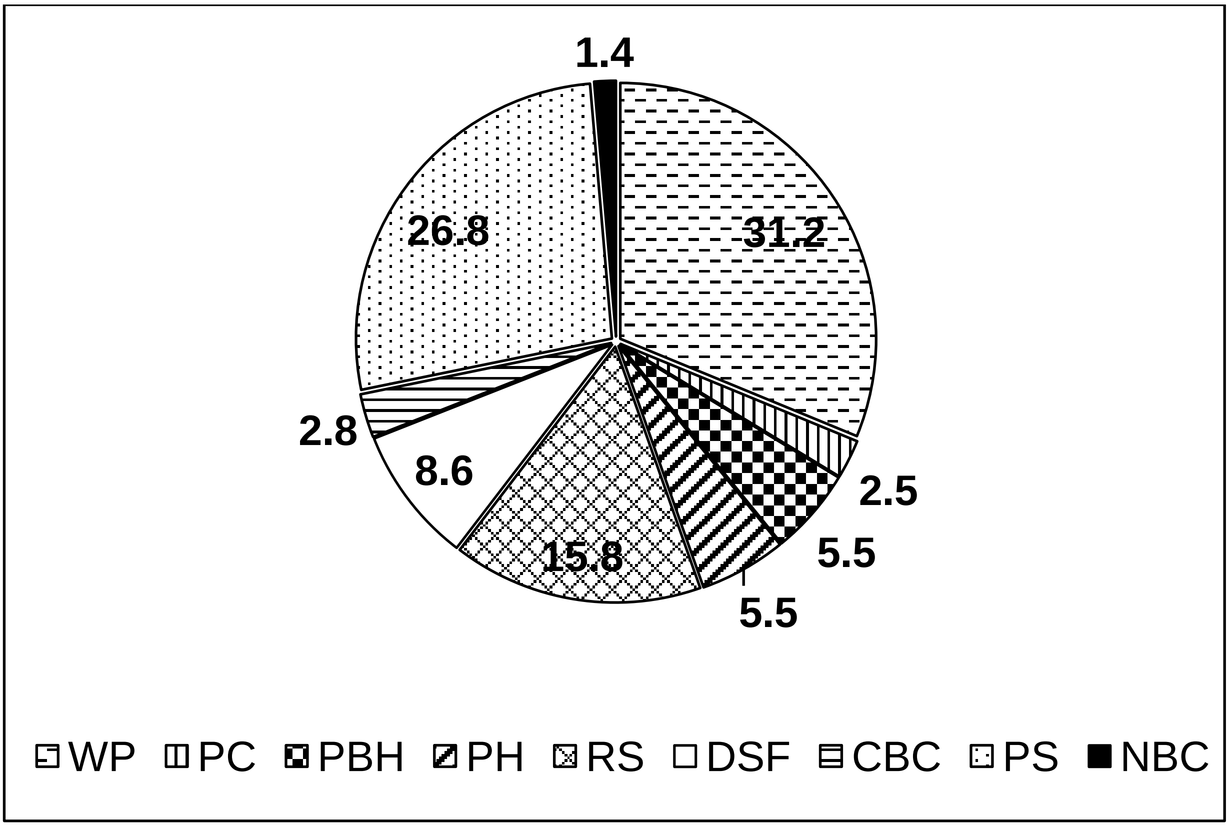

Fig. 2. Composition of bottom trawl catches (% by weight) in the western Bering Sea, 1995-1998 (WP – walleye pollock, PC – Pacific cod, PBH – Pacific black halibut, PH – Pacific halibut, RS – red squid, DSF – deepsea fishes, CBC – commercial bycatch, PS – prospective species, NBC – non-commercial bycatch).

Description of bycatch in the study area

Some geographic differences in bycatch quantities were observed by longitude (Fig. 3). Minimum bycatch values (19.7-137.8 $kg^{\cdot}hr^{-1}$) were registered west of 170°E (Olyutorsky Bay). In this area, maximum proportions of walleye pollock, red squid, deepsea species (mostly rockfishes) and commercial bycatch (mainly Pacific herring) were noted. Low shares of bycatch were also observed east of 180° (81.7-103.1 $kg^{\cdot}hr^{-1}$) where catches comprised large portions of Pacific black halibut, red squid and deepsea species. Bycatch values in the remaining part of the study area exceeded 200 kg·hr^{-1}(mean 468.1 kg·hr^{-1}). Maximum bycatch quantities were registered between 171-172°E (509.4 kg·hr^{-1}), 173-175°E (530.7-628.0 kg·hr^{-1}) and 177-178°E (992.0 kg·hr^{-1}). These differences related partly to distinctions in bottom relief and respective compositions of ichthyofauna. Maximum values of non-commercial bycatch were observed within the areas with narrow shelves and sharp continental slopes, where presently unutilized and non-commercial grenadiers, skates, eelpouts, snailfishes and small sculpins were most abundant. These areas featured more diverse catch compositions in comparison to areas having wide shelves and more gentle slopes (e.g. east of 180°). These benthic patterns resulted in high proportions of bycatch in catches because the fishing areas that contained greater species diversity also had greater numbers of species harvested, and smaller proportions of utilized species. Previously, geographic variations of bycatch quantity in the western Bering Sea had not been studied.

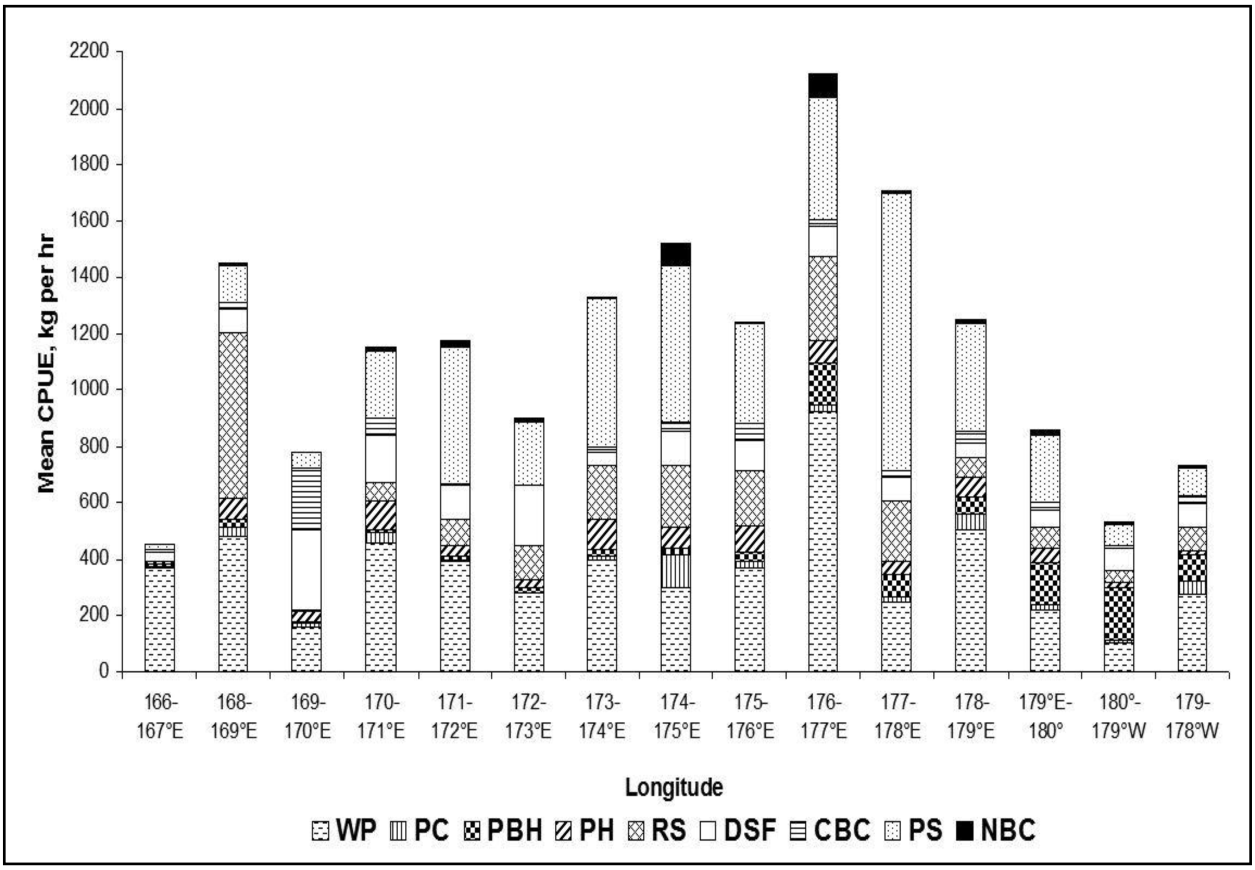

Fig. 3. Longitudinal variations of catch composition in the study area, average 1995-1998 (fish legends are the same as in Fig. 2).

Catch composition vs. depth

Catch composition changes with increasing depth because of the vertical stratification of ichthyofauna (Shuntov, 1965). Minimum bycatch values (24.4 kg·hr^{-1}) were observed at depths of less than 150 m (Fig. 4), where catches consisted mostly of walleye pollock. The proportion of non-commercial bycatch species increased with depth reaching a maximum value (3,239.5 kg·hr^{-1}) at depths over 650 m. The main reason of such changes was the gradual decrease of walleye pollock catches with depth and the corresponding increase in the proportion of currently unused grenadiers, skates, eelpouts and non-commercial snailfishes and soft sculpins, represented mostly by meso- and bathybenthic species whose abundance gradually increased with depth (Orlov, 1998). In the area under consideration, bottom trawl catch composition changes with depth were previously described in only a single paper (Borets et al. 2001), who, however, considered variations of catch composition in terms of the main families without taking the amount of bycatch into account.

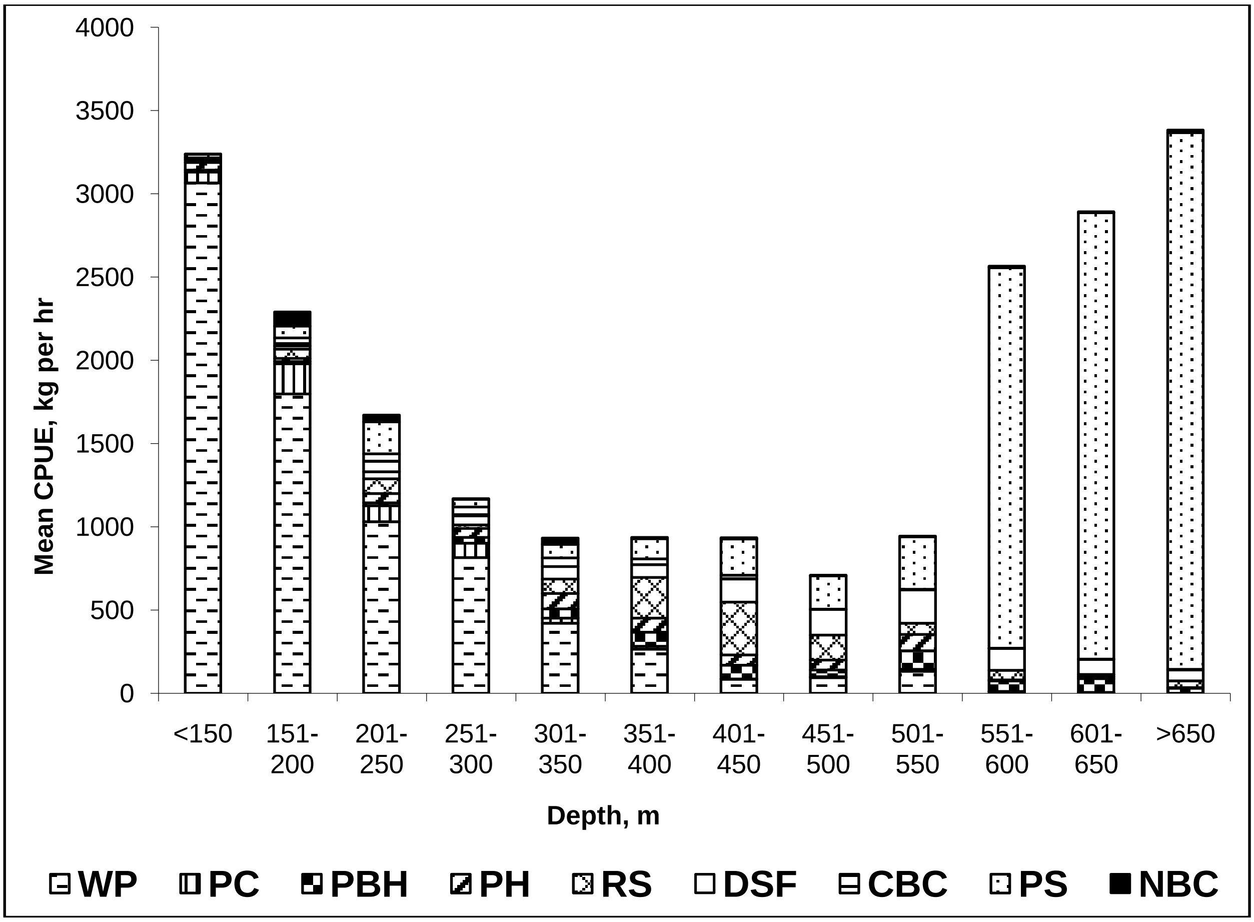

Fig. 4. Variations of catch composition in the study area by depths, average 1995-1998 (fish legends are the same as in Fig. 2).

Monthly variations of catch composition

Our studies were conducted annually from May to December, the western Bering Sea being covered by sea ice during the remainder of the year. However, even within this sampling period some monthly variations in bycatch proportions were observed (Fig. 5). The maximum bycatch values were observed in May (689.0 $kg \cdot hr^{-1}$) and in November (440.1 $kg \cdot hr^{-1}$). The earlier period was characterized by relatively small catches of walleye pollock. At this time, pollock spawn in coastal waters outside the study area (Shuntov et al. 1993). On the other hand, during the summer, grenadiers move from deeper to shallower depths (Tuponogov et al. 2008) thereby increasing the proportion of bycatch in the total catch. The high November share of bycatch is probably associated with decreasing amounts of red squid in catches. Red squid catches were high in August-October. In November, red squid catches decreased dramatically (down to 160.4 kg·hr^{-1}) and were further decreased in December (down to 58.2 kg·hr^{-1}). This drop was most probably associated with spawning of red squid in this period followed by the death of spawned individuals (Nesis, 1989). Minimum bycatch values were registered in December (74.3 kg·hr^{-1}). In this month, the proportion of Pacific cod and commercial bycatch (mostly flatfishes) increased, associated with wintering migrations of these species from the middle shelf to the outer shelf and upper slope (Moiseev, 1953). The highest values of Pacific halibut catches (243.4 kg·hr^{-1}) were in December that is the spawning time of the species which forms spawning aggregations within the outer shelf and upper slope (Novikov, 1964). In December, many presently unutilized and non-commercial fishes perform seasonal wintering migrations to deeper waters and their catches within the study area decreased. In the study area, monthly variations of bottom trawl catch composition were recently considered by Terentiev and Vasiletz (2005) using data obtained in February, June, and from September to December. Moreover, species composition was described in terms of selected species and families but bycatch quantities were not taken into consideration (Terentiev and Vasiletz, 2005).

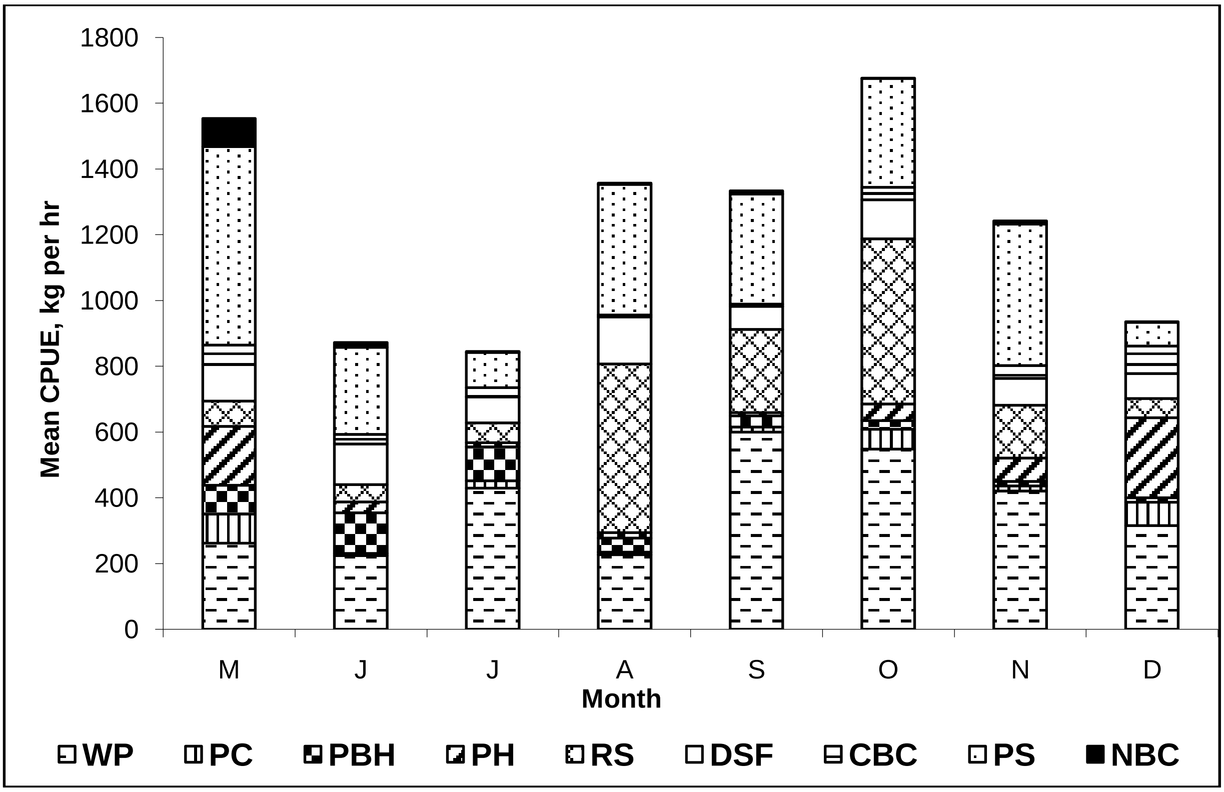

Fig. 5. Monthly variations of catch composition in the study area, average 1995-1998 (fish legends are the same as in Fig. 2).

Catch composition vs. time of day

Some groundfishes perform diurnal vertical migrations. This behavior is typical of many planktophage species such as Atka mackerel and Pacific Ocean perch. The behavior of non-commercial species is little understood. The present analysis showed that there are no well-pronounced diurnal changes in bycatch quantities (Fig. 6). However, the maximum bycatch values (502.3-527.2 kg·hr^{-1}) were registered from 13:00 to 18:00 hr. Minimum proportions of bycatch (64.3-120.7 kg·hr^{-1}) occurred between 19:00 and 24:00 hr. At these times, the shares of both prospective and non-commercial species in catches increased. This may be explained by the fact that the bulk of prospective species in catches were grenadiers and these consume mostly micronecton (midwater fish, squid and crustaceans) and, to a lesser extent, benthic invertebrates (crustaceans, bivalves, brittle stars, etc.) and, in the dark, are able to migrate into the water column (Tuponogov et al. 2008). Non-commercial species were comprised of snailfishes, soft sculpins, lumpsuckers, small poachers and small sculpins. The biology of these species is poorly understood. Therefore we cannot explain possible reasons for their diurnal changes of catch rates. In the western Bering Sea, diel variations in bycatch in bottom trawl fisheries were not previously described.

Currently unmarketable species that may have commercial value

Bycatch can be reduced significantly by exploiting species which are presently captured but discarded. This would require development of suitable processing techniques.

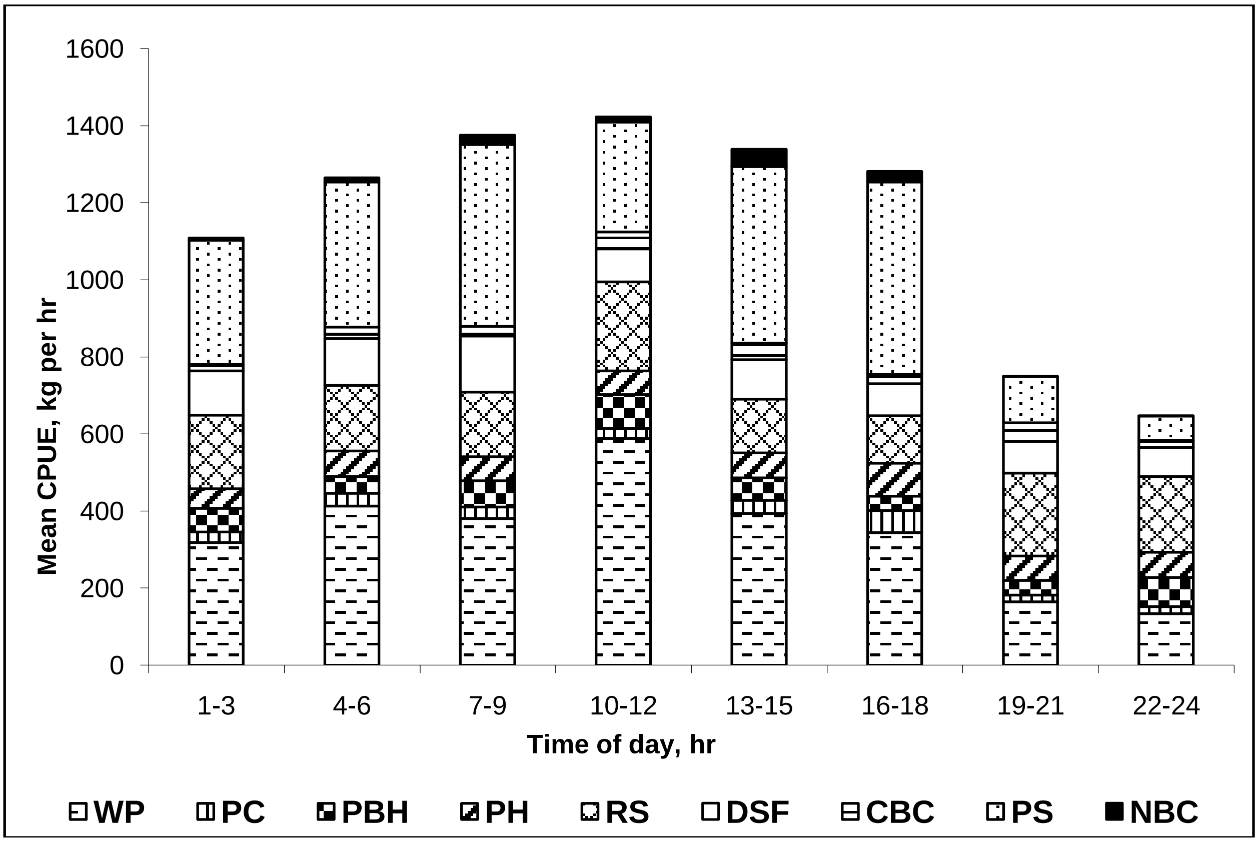

Fig. 6. Diurnal variations of catch composition in the study area, average 1995-1998 (fish legends are the same as in Fig. 2).

The most promising species with prospects for utilization are the resources of grenadiers. In the western Bering Sea, the estimation of their biomass on the outer shelf and upper continental slope was 26,000-56,000 tonnes (Lapko et al. 1999; Borets et al. 2001; Glebov et al. 2003). In the western Bering Sea during the last decades, the total biomass of grenadiers has been stable (113,000-210,000 tonnes) and their annual catch in this area has not exceeded 10% of total biomass (Tuponogov, unpubl. data). Daily average catches of large trawlers may have been between 20 and 30 tonnes (Tuponogov et al. 2008). All grenadiers may provide raw materials for highly palatable canned liver (Fig. 7). Giant (*Albatrossia pectoralis)* and Pacific (*Coryphaenoides acrolepis)* grenadiers have large orange eggs that can be used for processing to canned goods. Popeye (*C. cinereus)* and Pacific grenadiers are characterized by high percentages of fillet (31.5-40.1%) and can be used for direct human consumption. Their meat has a high content of protein (8.5-17.6%). The flesh of the giant grenadier contains too much moisture (90.4-92.9%) and therefore is unsuitable for direct consumption but maybe used for processing to animal and pet food. If appropriate processing technology was developed, the flesh of grenadiers might be able to be treated to form surimi, which is currently manufactured from walleye pollock and cod (Orlov, 2005a). The current market prices of grenadiers (Table 2) are low in comparison to those for other deep-water fishes (rockfishes, halibuts, thornyheads, etc.) but are comparable with those for arrowtooth flounder (*Atheresthes stomias)* and Dover sole (*Microstomus pacificus)* which have recently been harvested for human use in Alaskan waters and off the west coasts of USA (Orlov, 2005a).

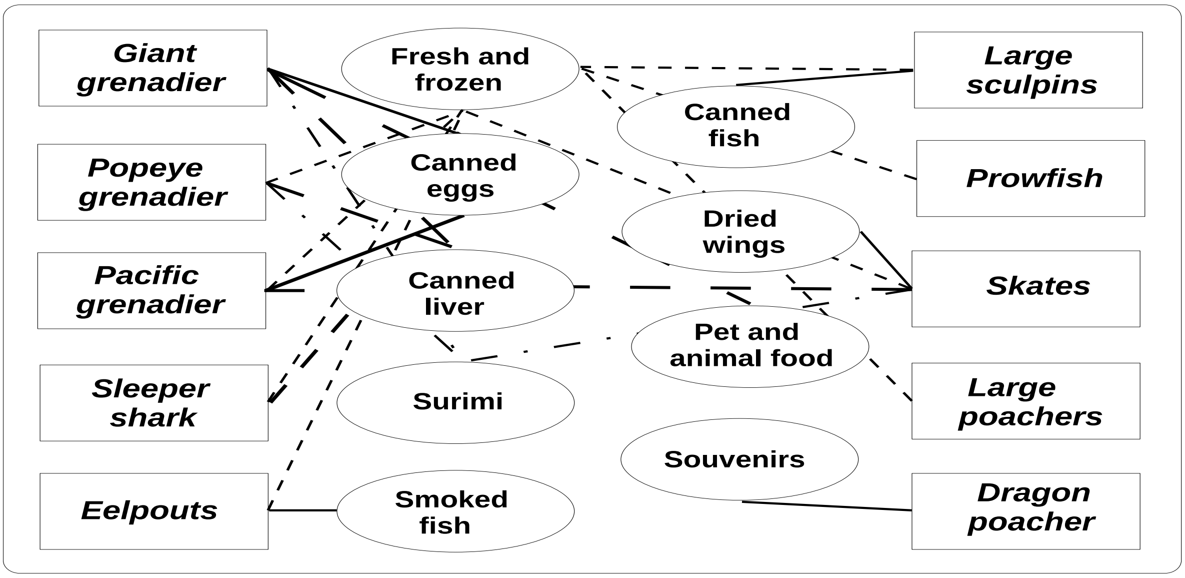

Fig. 7. Scheme of possible processing directions of currently unmarketable prospective fish species.

Table 2. Processing and marketing of grenadiers in Russia (according to Orlov, 2010).

Processing type (price)	Production	Price		
		Wholesale	Consumer	Export
Frozen (USD per kg)	Round	1.83-2.07	2.17-2.53	0.87-1.07
	Gutted, head-off and tail-off			1.07-1.40
	Head-off			0.93-1.10
	Eggs	2.67		
	Liver	1.07		
Canned food (USD per can)	Eggs	1.23-1.64		
	Liver	3.75-7.49		

Recently, some Russian companies started bottom trawl fisheries for grenadiers in the northwestern Pacific, exporting the catch to China and the British Virgin Islands. In these countries, current market prices are sufficiently high as to make fisheries for grenadiers profitable. Other important unutilized fishery resources are skates, for which the biomass in the study area was recently estimated as 16,000-54,000 tonnes (Lapko et al. 1999; Borets et al. 2001; Glebov et al. 2003). Skates are traditional fishery targets in Southeast Asia, where skate wings are used for consumption (Ishihara, 1990). Recently, some Russian companies started to export skate wings to China, Hong Kong and British Virgin Islands at prices between 0.9 and 1.3 USD per kg). Skates also may be marketed in Japan and Korea. Fishing for skates may prove profitable, given their high price in the Asian fish markets. The livers of skates are rich in nutrients, though less so than those of sharks, and therefore could be used for extraction of oil. Skates have a strong and thick skin that may be used for manufacture of many leather articles. The flesh of skates is suitable for processing to fish meat jelly, which is used in the preparation of various Japanese national dishes (Ishihara, 1990) and is appropriate for processing to human foodstuffs (Ershov et al. 2002).

Another prospective fishery resource is the Pacific sleeper shark, which has increased in abundance in the North Pacific recently (Wright and Hulbert, 2000; Orlov, 2005b). In the study area, in 2002 its biomass was estimated as 88,000 tonnes (Glebov et al. 2003). In the 1930s in Californian waters, USA fishers undertook limited fisheries for this species (Walford, 1935). Likewise, in the North Pacific in the 1970s, Japanese fishers exploited this species (Zolotova, 1978). The value of the sleeper shark as a target species is difficult to judge because no studies have been conducted on its processing properties and chemical composition.

The weight of the liver of Pacific sleeper sharks can reach 11.3% of the body weight (average of 9.2-9.7%) (Tanaka et al. 1982; Glubokov, 2004) and contain more vitamin A than that in other deepwater sharks (Higashi et al. 1955). Tinker (1978) was concerned, however, that the meat of sleeper shark contained a toxin, which evoked drinking-like intoxication when it was consumed. The research on the congeneric species Greenland shark (*S. microcephalus)* (Bykov et al. 1998) shows that its meat has good quality food characteristics, contains 9.8% protein but is very fatty (the average fat content is 12%). The cooked meat of Greenland shark is tough, and resembles the meat of great sturgeon (*Huso huso)*. After soaking in water or a weak solution of soda, the meat of this shark becomes quite fit for cold smoking or for processing into fish mince. Further research on the technological properties of Pacific sleeper shark is required.

Large sculpins (family Cottidae) are important species in inshore fisheries. The most promising species are abundant in the study area, especially yellow (*Hemilepidotus jordani)*and banded (*H. gilberti)* Irish lords, purplegrey sculpin (*Gymnocanthus detrisus)* and armorhead scuplin (*G. galeatus)*, giant sculpin (*Myoxocephalus polyacanthocephalus)* and plain sculpin (*M. jaok)*, bigmouth sculpin (*Ulca bolini)* and spectacled sculpin (*Triglops scepticus)* (Tokranov, 1985, 2002). The biomass of sculpins in the study area was estimated at 13,000-71,000 tonnes (Lapko et al. 1999; Borets et al. 2001; Glebov et al. 2003). Catches of sculpins also comprise considerable bycatch of cod and flatfish but their fishery is undeveloped, probably due to their lack of market acceptance despite the fact that processing technology for some sculpins was developed about three decades ago (Didenko et al. 1983).

Various eelpouts (family Zoarcidae) are of some interest for commercial fishing. They are abundant in some areas and made up a considerable part of the bycatch. Their biomass in the study area recently was estimated at 4,000-29,000 tonnes (Borets et al. 2001; Glebov et al. 2003). The results of technological studies conducted by Pacific Fisheries Research Center (TINRO-Center, Vladivostok, Russia) showed that eelpouts are acceptable for processing to human food. Their flesh is suitable for smoking and processing to various foodstuffs.

The flesh of prowfish (*Zaprora silenus),* which has a dense consistency and white color, resembles that of cod or Pacific halibut. Some Japanese fishermen use prowfish in preparing the national Japanese dish “sashimi”. Caught in the study area, prowfish are mostly discarded, probably because of their low abundance and their unappetizing appearance.

Large poachers of the genus *Podothecus* are of interest for commercial fishing. Despite their relatively low abundance, the poachers are very popular in Japanese fish markets. In Japan, they are delivered directly to fish restaurants. Some poachers (for instance, the dragon poacher (*Percis japonica*) have exotic appearances and may be used for manufacturing souvenirs.

Conclusion

The right choice of optimum fishing areas, depths, seasons and time of the day could minimize the share of non-commercial species in catches. The amount of bycatch had some geographical patterns. The minimum values of non-commercial bycatch were registered west of 170°E (Olyutorsky Bay) and east of 180° while its maximum values were observed within the areas with narrow shelf and sharp continental slope between 171-172°E, 173-175°E and 177-178°E.

The amount of bycatch changed with capture depth. The minimum bycatch values were observed at depth of less than 150 m while the proportion of non-commercial bycatch species increased with depth, reaching maximum values at depths over 650 m. Some seasonal changes of bycatch values were detected. The maximum bycatch values were observed in May and November, and minimum bycatch values were registered in December. There are no well-pronounced diurnal changes in bycatch quantities. However, the maximum bycatch values were found from 13:00 to 18:00 hr. Minimum proportions of bycatch occurred between 19:00 and 24:00 hr. Bycatch can be reduced significantly by the fishery retaining and landing grenadiers, eelpouts, skates, large sculpins, poachers and some other species, which presently are not being utilized. Grenadiers may be used for canned liver and eggs and the flesh may be processed to human or animal food and probably to surimi. Skate wings are suitable for human consumption. Sculpins and eelpouts are suitable for processing to canned fish or human food. The remainder of the non-commercial bycatch species except for snailfishes, whose soft flesh contains too much water, may be processed to fish powder.

Bycatch species cannot compete with traditionally harvested species since 1) they have a lower market price, 2) most of them (except for grenadiers) have low abundance, 3) there are limited markets that accept such trade from Russia, 4) some of these species are new or poorly known to customers and therefore are hardly salable. However, most of them may be used for direct human consumption. This would require development of appropriate processing techniques, searches for new fish markets, and promoting new products to customers. Given the recent decline in catches of many commercially important species, it is likely that the exploitation of some of these bycatch species will soon become feasible. The fullest utilization of bycatch should be achieved in accordance with resolutions of the United Nations General Assembly dealing with sustainable fisheries, including the FAO Code of Conduct for Responsible Fisheries, the Convention on Biological Diversity, the principles of the ecosystem-based approach to fisheries management, and the requirements to manage multispecies (mixed) fisheries.

References

Adlerstein, S.A. and R.J. Trumble.1993. Management implications of changes in bycatch rates of Pacific halibut and crab species caused by diel behaviour of groundfish in the Bering Sea. In: Fish behaviour in relation to fishing operations (eds. C.S. Wardle and C.E. Hollingworth). pp. 211-215. ICES Marine Science Symposia 196. ICES Headquarters, Copenhagen.

Alverson, D.L. 1996. Discarding: a part of the management equation. In*:* Proceedings of the East Coast Bycatch Conference (eds. C. Castro, T. Corey, J. DeAlteris and C. Gagnon). pp. 11-13. Rhode Island Sea Grant, Rhode Island, USA.

Alverson, D.L. 1997. Global assessment of fisheries bycatch and discards: a summary overview. In: Global trends: fishery management (eds. E.K. Pikitch, D.D. Huppert and M.P. Sissenwine). American Fisheries Society Symposium 20. pp.115-125. American Fisheries Society, Bethesda, Maryland, USA.

Alverson, D.L. 1999. Some observations on the science of bycatch. Marine Technology Society Journal 33:6-12.

Alverson, D.L. and S.E. Hughes. 1996. Bycatch: from emotion to effective natural resources management. Reviews in Fish Biology and Fisheries 6:443-462.

Alverson, D.L., M.H. Freeberg, S.A. Murawski and J.G. Pope.1994. A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper 339:1-233. FAO, Rome.

Anderson, O.F. and M.R. Clark. 2002. Analysis of bycatch in the fishery for orange roughy, *Hoplostethus atlanticus*, on the south Tasman Rise. Marine and Freshwater Research 54:643-652.

Baxter, B. and S. Keller (eds.). 1996. Solving bycatch: considerations for today and tomorrow. Alaska Sea Grant College Program Report No. 96-03. University of Alaska Fairbanks, Alaska, USA. 336 pp.

Baxter, B. and S. Keller (eds.). 1997. Fisheries bycatch: consequences and management. Alaska Sea Grant College Program Report No. 97-02. University of Alaska Fairbanks, Alaska, USA.160 pp.

Broadhurst, M.K., S.J. Kennelly and C.A. Gray. 2002. Optimal positioning and design of behavioural type bycatch reduction devices involving square-mesh panels in penaeid prawn-trawl codends. Marine and Freshwater Research 53:813-823.

Borets, L.A., A.B. Savin, S.P. Bomko and S.A. Palm. 2001. Condition of the bottom fish communities in the north-western Bering Sea in the end of 1990’s. Voprosy Rybolovstva 2: 242-257. (In Russian).

Bykov, V.P., G.P. Ionas, G.N. Golovkova, A.P. Didenko, V.N. Akulin, L.I. Perova, A.B. Odintsov, L.L. Konstantinova, Y.F. Dvinin, G.S. Christoferzen and L.P. Borisova. 1998. Guide to chemical composition and technological properties of marine fishes. VNIRO Publishing, Moscow. 223 pp.

Clucas, I. 1998. La fauna acompañante? Ésunabonificacióndel mar? Infopesca Internacional38: 33-37. (In Spanish with English summary).

Davis, M.W. 2002. Key principles for understanding fish bycatch discard mortality. Canadian Journal of Fisheries and Aquatic Science 59:1834-1843.

Dewees, C.M. and E. Ueber. 1990. Effects of different fishery management schemes on bycatch, joint catch, and discards. Summary of a national workshop, San Francisco, California, January 1990. California Sea Grant College Program Report Series. La Jolla, California, USA, 57 pp.

Didenko, A.P., G.A. Borovskaya, L.I. Drozdova and N.A. Lavrova. 1983. Techno-chemical characteristic and recommendations on rational use of sculpins. Izvestiya TINRO 108:13-19. (In Russian).

Ermakov, Y.K. 2002. Bycatch composition on trawl fishing of herring in the Bering Sea and Sea of Okhotsk. Voprosy Rybolovstva 3:91-104. (In Russian).

Ermakov, Y.K. and K.A. Karyakin. 2003. Bycatch composition in trawl fisheries of Alaska pollock in the Bering Sea and Okhotsk Sea. Voprosy Rybolovstva 4:435-450. (In Russian).

Ermakov, Y.K. and O.Z. Badayev. 2005. The analysis of bycatch obtained during bottom longline fishery in the Far Eastern Seas of Russia. Voprosy Rybolovstva 6:86-97. (In Russian).

Ershov, A.M., B.F. Petrov, V.V. Korchunov and O.A. Nikolaenko. 2002. Problems of using of thorny skate for human food purposes. In: Prospects of development of Russian fisheries complex – XXI century. Abstracts of Presentations at the Scientific-Practical Conference, Moscow, 27-28 June 2002. pp. 101-102. VNIRO Publishing, Moscow. (In Russian).

Feidi, I. 1989. Economic utilization of fish bycatch and by-products in the Arab Gulf region. Paper prepared for Seminar on Economic Utilization of Waste. INFOSAMAK/FAO, Jeddah, Saudi Arabia. 56 pp.

Fonteyne, R. and H. Polet. 2002. Reducing the benthos bycatch in flatfish beam trawling by means of technical modifications. Fisheries Research 55:219-230.

Glebov, I.I., G.M. Gavrilov, A.N. Starovoytov and V.V. Sviridov. 2003. Structure and interannual dynamics of benthic fish communities in the northwestern Bering Sea. Voprosy Rybolovstva 4:575-589. (In Russian).

Gloubokov, A.I. 2004. New data on Pacific sleeper shark *Somniosus pacificus* (Squalidae) from the northwestern Bering Sea. Voprosy Ikhtiologii 44:357-364. (In Russian).

Grainger, R. 1997. Recent FAO activities related to bycatch and discard issues. In*:* Fishery and aquaculture statistics in Asia (ed. V.T. Sulit). Proceedings of the FAO/SEAFDEC Regional Workshop on Fishery Statistics.Vol. 2. pp.188-191. SEAFDEC, Bangkok.

Hall, M.A., D.L. Alverson and K.I. Metuzals. 2000. Bycatch: problems and solutions. Marine Pollution Bulletin 41:204-219.

Hickey, W.M., G. Brothers and D.L. Boulos. 1993. Bycatch reduction in the northern shrimp fishery. Canadian Technical Report of Fisheries and Aquatic Science 1964:1-47.

Higashi, H., T. Kaneko and K. Sugii. 1955. Studies on utilization of the liver oil of deep sea sharks – XI. Vitamin A content and molecular-distillation of the liver oil of deep sea sharks. Bulletin of Tokai Regional Fisheries Research Laboratory 11:448-453.

Isaac, V.J. and T.M.P. Braga. 1999. Bycatch in the marine fisheries off northern Brazil. Arquivos de Ciencias do Mar 32:39-54 (In Portuguese with English summary).

Ishihara, H. 1990. The skates and rays of the western North Pacific: an overview of their fisheries, utilization, and classification. In: Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (eds. H.L. Pratt, Jr., S.H. Gruber and T. Taniuchi). U.S. Department of Commerce, NOAA Technical Report NMFS 90:485-497.

Kelleher, K. 2005. Discards in the world's marine fisheries. FAO Fisheries Technical Paper 470: 1-131. FAO, Rome.

Kenelly, S. and M. Broadhurst. 1998. Reducing bycatch: we show the world. Fisheries NSW 4 (Spring):4-5.

Lapko, V.V., M.A. Stepanenko, G.M. Gavrilov, V.V. Napazakov, A.M. Slabinsky, O.N. Katugin and M.M. Raklistova. 1999. Composition and biomass of nekton within near-bottom layers in the northwestern Bering Sea in autumn 1998. Izvestiya TINRO 126:145-154. (In Russian).

Malchoff, M.C. (ed.) 1999. Proceedings of the Sea Grant bycatch workshop. New York Sea Grant Extension Program, Riverhead, New York, USA. 32 pp.

Moiseev, P.A. 1953. Cod and flounders of the far eastern seas. Izvestiya TINRO 40:1-287. (In Russian).

Nesis, K.N. 1989. Teuthofauna of the Sea of Okhotsk. Biology of squids *Berryteuthis magister* and *Gonatopsis borealis* (Gonatidae). Zoologichesky Zhurnal 68:45-56. (In Russian).

Novikov, N.P. 1964. Basic elements of the biology of the Pacific halibut (*Hippoglossus hippoglossus stenolepis* Schmidt) in the Bering Sea. Izvestiya TINRO 51:167-207. (InRussian).

Orlov, A.M. 1998. Demersal ichthyofauna of Pacific waters around the Kuril Islands and southeastern Kamchatka. Biologiya Morya 24:144-160. (In Russian).

Orlov, A.M. 2005a. Groundfish resources of the northern North Pacific continental slope: from science to sustainable fishery. In: Proceedings of the Seventh North Pacific Rim Fisheries Conference. May 18-20, 2004. Busan, Republic of Korea. pp.139-150. Anchorage: Alaska Pacific University, Alaska, USA.

Orlov, A.M. 2005b. Pacific sleeper shark: problem for fisheries or prospective fisheries resource? Rybnoye Khozyaistvo 3:60-62. (In Russian).

Orlov, A.M. 2008. Bycatch reduction of multispecies bottom trawl fisheries: some approaches to solve the problem in the Northwest Pacific. In: Reconciling fisheries with conservation. Proceedings of the Fourth World Fisheries Congress. American Fisheries Society Symposium 49.pp. 241-258. American Fisheries Society, Bethesda, Maryland, USA.

Orlov, A.M. 2010. Giant and popeye grenadiers of the North Pacific. PowerPoint presentation presented at the workshop "Can ecosystem-based deep-sea fishing be sustained?". 31 August – 3 September 2010, Chateau de Neuville-Bosc, France.

Parin, N.V. 2004. Ichthyofauna of the seas of Russia: biological diversity and fishery potential. Izvestiya TINRO 137: 226-231. (In Russian).

Perra, P. 1992. Bycatch reduction devices as a conservation measure. Fisheries 17:28-30.

Schoning, R.W., R.W. Jacobson, D.L. Alverson, T.H. Gentle and J. Auyong (eds.). 1992. Proceedings of the National Industry Bycatch Workshop. February 4-6, 1992, Newport Oregon. Natural Resources Consultants, Seattle, Washington, USA. 222 pp.

Shuntov, V.P. 1965. Vertical zonality in distribution of fishes in the upper bathyal of the Sea of Okhotsk. Zoologicheskii Zhurnal 44:1678-1689. (In Russian).

Shuntov, V.P., A.F. Volkov, O.S. Temnykh, and E.P. Dulepova. 1993. Walleye pollock in ecosystems of the Far Eastern Seas. TINRO, Vladivostok, 426 pp. (In Russian).

Tanaka, S., K. Yano and T. Ichihara. 1982. Notes on a Pacific sleeper shark, *Somniosus pacificus*, from Suruga Bay, Japan. Journal of the Faculty of Marine Science and Technology, Tokai University 15: 345-358.

Terentiev, D.A. and P.M. Vasilets. 2005. Catch structure by fishery gears in the northwestern Bering Sea. Izvestiya TINRO 140:18-36 (In Russian).

Tinker, S.W. 1978. Fishes of Hawaii, a handbook of the marine fishes of Hawaii and the Central Pacific Ocean. Hawaiian Service Inc., Honolulu. 568 pp.

Tokranov, A.M. 1985. Sculpins – prospective targets of inshore fishery. Rybnoye Khozyaistvo 5:28-31 (In Russian).

Tokranov, A.M. 2002. Untraditional fishery resources: is the use of their stocks realizable today? Rybnoye Khozyaistvo 6:41-43. (In Russian).

Tuponogov V.N., A.M. Orlov and L.S. Kodolov. 2008. The most abundant grenadiers of the Russian Far East EEZ: distribution and basic biological patterns. In: Grenadiers of the world oceans: biology, stock assessment, and fisheries (eds. A.M. Orlov and T. Iwamoto). American Fisheries Society Symposium 63. pp. 285-316. American Fisheries Society, Bethesda, Maryland, USA.

Vinnikov, A.V. and D.A. Terentiev. 1999. Main directions of bycatch studies during conduction of various fisheries in coastal Kamchatkan waters. In: Fisheries studies of the world oceans. Proceedings of the International Scientific Conference. pp. 117-119. Far East Fisheries University, Vladivostok. (In Russian).

Walford, L.A. 1935. The sharks and rays of California. California Fish and Game Fishery Bulletin 45:1-66.

Walker, T.I., R.J. Hudson and A.S. Gason. 2002. Catch evaluation of target, by-product and by-catch species taken by gillnets and longlines in the shark fishery of south-eastern Australia. NAFO Scientific Council Research Document no. 02/114. NAFO Headquarters, Dartmouth. 30 pp.

Wright, B.A. and L. Hulbert. 2000. Shark abundance increases in the Gulf of Alaska. PICES Press 8:16-17, 22.

Zolotova, Z.K. 1978. Shark fishery prospects in the World Ocean. Obzornaya Informatsiya CNIITEIRKh, Ser. 1. 6:1-30. (In Russian).

Received: 23/04/2011; Accepted 31.10/2011 (MS11-30)