2015 Annual Report to the PCCRC
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Title: The effects of variation in fishing restrictions and environmental conditions on vital rates of Steller sea lions from Russian rookeries with contrasting population trends

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PROJECT INTRODUCTION

Although Steller sea lion (SSL) populations have ceased their decades-long decline throughout most of their range, this is not the case for SSL in the Western and Central Aleutians and in the nearby Commander Islands (Russia), where abundance continues to decline. This may be due in part to low reproductive rates, which led to new fishing regulations in the Aleutian Islands that were controversial. Unfortunately, there presently are no empirical data available on the vital rates of SSL in the Western or Central Aleutian Islands. However, just across the border into Russia, lie the Commander Islands, less than 200 miles from the western-most United States SSL rookery. Steller sea lions from the Commander Islands are genetically similar to Aleutian Islands SSL and are also part of the Western SSL “stock”, and SSL abundance on the Medny Island (Commander Islands) rookery has shown similar instability as in the Western Aleutians. We have direct measurements of SSL vital rates at the Commanders and seven other rookeries in Russia. Studies of SSL from the Medny Island rookery (Commander Islands) may provide valuable insights for comparison to the Western Aleutians because the Commanders have been protected by a 30 mile no-fishing zone since the late 1950s. In our first year we aimed to use demographic data collected in the Commander Islands (where SSL pup counts have been decreasing) and in the Kuril Islands (where SSL populations are increasing) over the years 2000 to 2011 to compare and contrast areas of differing population trends. Our primary goals in Year 1 were to compile all of the data, determine the population age structure in the various regions, and produce estimates for survival and reproductive rates. In Year 2, our goals were to investigate the relationships between SSL abundance trends and vital rates and prey, fishing activity and environmental conditions as well as presence of potential competitors (e.g. northern fur seals) and predators (killer whales). Our results should lead to insights about the causes of declining populations and the potential for fisheries interactions, and should be very applicable to the search for an understanding of the SSL situation in the Western and central Aleutian Islands.

SUMMARY OF PROGRESS DURING 2015

Work Completed

Our first annual report (Jan. 2014) covered work conducted from September 2013 through December 2013, and included a preliminary analysis of mark-recapture data from 6 rookeries in the Russian Far East: Medny Island, in the Commander Islands, which is genetically placed into the Western stock. Kozlov Cape, in Eastern Kamchatka, and four Kuril Islands rookeries: Antsiferov, Lovushki, Raykoke, and Brat Chirpoev. Our analysis included branded cohorts born from 1989-2008, and post-branding observations conducted from 2002 to 2011. During that period more than 4500 pups were branded, and on over 3000 observation days more than 9000 re-sightings of 41% of the previously marked animals were collected.

In our second annual report (Jan. 2015), we reported our progress for the year 2014, in which we refined our analyses of vital rates, including survival, birth and emigration rates. Survival analyses were conducted using the Cormack-Jolly-Seber method with the program MARK using an R interface provided by RMark. For birth rates, we used an Open Robust Design Multi-state with State Uncertainty and Seasonal Effects (RDMSOpenMCSeas) model in MARK. This model utilizes severe probabilities to describe seasonal state changes and includes the probability that state may be assigned incorrectly if a female was seen without a pup. We constructed recapture histories with 10 primary periods from age 4 to 22 for the Kuril Islands, and through age 15 elsewhere. Each primary period contained 6 secondary occasions, each representing a week, covering 6 weeks since June 1. With our refined estimates of survival and birth rates, we constructed Leslie matrices to estimate the population projection parameters and compare the projections to recent population trend analyses. We also made estimates of emigration for each of the major regions. Finally, we compiled data on key environmental factors including oceanographic variables and importantly fishing effort for key prey species throughout the Russian Far East.

In this past year we performed additional analyses of vital rates and also extrapolated them through 30 years of age using a logistic growth rule. We performed sensitivity analyses to identify which vital rates were most likely responsible for the declining population trend in the Commander Islands. Census data but not vital rates data are available for the declining population in the Western and Central Aleutian Islands, so in order to determine whether census data can be used to predict vital rates, we combined our estimates of vital rates into population models and compared results with observed census data for each rookery along Russian Far East. We also refined our survival models in order to identify variation in survival over time. We then refined our fishery analysis, based on newly obtained fishery data set in order determine unbiased estimates of fish catch per unit effort and to estimate catch densities in areas at which Steller sea lions may be present. We then evaluated the relationships between the changes we observed in the fishery and vital rates over space and time.

Results

Vital rates and population trends

Although we have detailed vital rates data for the Russian Far East for nearly 2 decades, this is not the case in the Western and Central Aleutians, where mark-resight studies commenced only recently. For fully informed management decisions about these areas where the population is still declining, it would be valuable to have estimates of mortality and fecundity, which do not currently exist. However, good census date do exist for much of the Aleutians, so we sought to use our vital rates and census data to determine how well time-series of census data could be used for vital rates estimates. Using count data to predict vital rates is challenging for many reasons, including the effects of the population buffering mechanisms that often operate in populations of large mammals that have several overlapping generations.

With mark resight data that we obtained in the Russian Far East (Fig 1) in 2002-2011 we estimated average age specific survival and birth rates up to age 22. Using these estimates and assuming that the pattern of senescence in survival would follow a negative logistic growth rule we were able to extrapolate vital rates until the age of 30 and cover the entire lifespan of Steller sea lions (Fig. 2 - 3). We then incorporated those rates into population models based on age-structured Leslie matrix models to predict population trends and to compare the predicted trends with our observed census data (Fig. 4 - 6).

We found that the population trends predicted by the population models closely matched trends based on census data within the timeframe of our study. The only rookery at where the population is currently declining in our study was Medny Island (Fig. 4). At Medny Island we detected lower values for both adult survival and birth rates. The sensitivity analysis based on the life table response illustrated that the population decline cannot be attributed to only one of those rates. Even though the differences in birth rates between Kuril Islands and Commander Islands were higher than the differences in adult (ages 4-11) survival, the effect of those differences on the population growth rate were about the same.

One unexpected result was that our population trend predictions from the vital rate estimations suggested very high population growth rate at Kozlov Cape, mostly due very high adult survival. This finding was in agreement with the census data for the early part of our study, when pup production increased between the year 2000 until at least 2006 - 2007. However, because the population on Kozlov Cape is at a very low abundance, the growth in absolute numbers was also low (Fig. 5).

At all Kuril Islands rookeries, the positive population growth predicted by the Leslie population model was very close to the population trends based on our census data, indicating positive population growth over the last decade (Fig. 6).

Predicted survival and fecundity rates were consistent with observed pup counts at all rookeries in Russian Far East. However, non-pup counts were typically half the predicted values. This difference was greater at Kuril Islands rookeries than on the Commanders and Kozlov Cape, probably because of inter-site variability in detection probability. Census data are clearly affected by factors that can vary throughout the range, not to mention by undocumented migration levels, thereby complicating their use to predict vital rates.

Variation in survival rates over time

We found significant differences in vital rates between regions that explained for the most part whether the regional population was declining or growing. However, when we previously compared vital rates with region-specific environmental characteristics for the whole time period of our study, we did not identify any factors that could explain those regional vital rates differences. However, there were some obvious changes in vital rates over the full time-series of our data, so we then set out to quantify that time variation and then more carefully examine the effect of environmental changes over time.

We estimated the time variation of survival rates for pups, juveniles and adult females using Cormack-Jolly-Seber models. For all sites in the Kuril Islands our data allowed us to evaluate variation for the time period 2001-2010, while on Medny Island the data were available from 1996, and from 2000 on Kozlov Cape. We found that survival rates varied differently over time between regions and ages. For example, in the Kuril Islands the models did not provide any evidence of variation in survival over time for adults and juveniles. Only pup survival increased in the Kuril Islands (Fig. 7).

Over the timeframe of our research, survival of adults and juveniles varied only in two closely located areas: Medny Island (Commander Islands) and Kozlov Cape (Kamchatka coast), and the time variation was very similar (Fig. 8 and 9). We previously reported that there were significant levels of temporary (seasonal or for multiple years) migration from Commander Islands toward Kamchatka. Thus it is not surprising that there are similarities in juvenile survival variation, given that the juveniles from both breeding areas likely spend much time in the same area along Kamchatka. At both rookeries, survival increased from 1996 and reached its maximum levels around the years 2003 - 2005, but then started to decline. Although the time pattern was similar at both rookeries, the changes in survival at Kozlov Cape were much greater. Such changes in juvenile survival are not surprising given that it is often the first vital rate that changes in response to environmental changes.

Adult survival on Medny Island and Kozlov Cape increased over time until recently, with a large drop in the year 2011, on both Medny and Kozlov Cape. The early rate of increase was much higher at Kozlov Cape than on Medny Island. By the year 2008-2009 adult survival on Kozlov Cape reached its maximum level. Interestingly, pup survival also increased along with increases in adult female survival on Kozlov Cape, while pup survival on Medny Island did not change greatly.

In last year’s report we highlighted that survival of pups may be related to female reproductive strategies. Our recent results also support this and demonstrate that on both Medny Island and Kozlov Cape adult females that do not give birth in particular year survive better. Therefore, we hypothesized that increases in adult female survival and pup survival are closely related to female reproduction strategies, such as not pupping every year.

High variation in juvenile survival along with recent drops in adult survival, however, may also indicate that the positive population growth observed at Kozlov Cape may last not for a much longer. These findings lead us to suggest that factors that affect Steller sea lion populations have changed recently in the Bering Sea, and these variations may be closely related to changes in the environment where Steller sea lion reside.

Environmental Factors

Initially we evaluated whether fishery catch levels near Steller sea lion rookeries could explain the regional differences we observed in vital rates and population trends. Commercial fisheries were completely excluded from the conservation zone that extended 30nm from the shore of the Commander Islands over the last 50 years. Even though there has been no significant fishery along Commander Islands, from satellite tracking and haulout observations, we found that Steller sea lions usually migrated seasonally to the Kamchatka Peninsula. Those long-distance movements may suggest that prey resources along Commander Islands are not sufficient during the winter time, a possible food limitation that is unlikely to be related to any fishing activity near the Commander Islands.

Historical movements of Steller sea lions from the Aleutian Islands toward the Western Bering Sea, which may have occurred in very high numbers in the past, suggest that the feeding area along this area may have been very important for Steller sea lions, at least in the past. Therefore, the commercial fisheries along the Kamchatka Peninsula and Western Bering Sea may have a potential effect on Steller sea lion vital rates, given that they often stay in the area for a significant amount of time.

A summary of the commercial fishery catches indicated that the major catch occurred along the Kamchatka Peninsula and north towards Chukotka. The Atka mackerel fishery occurred mostly in the Kuril Islands and the southern part of Kamchatka peninsula. Interestingly, variation in Steller sea lion survival rates was found only in the areas located near to Kamchatka’s main fishery regions.

In our preliminary analysis of commercial fishing data we found that Steller sea lion survival correlated positively with pollock catch levels and suggested that both the fishery and the survival of sea lions may depend on similar environmental factors. However, those results were based on a simple summarization of the catch data that we could obtain from Russian sources, and did not account for many important factors such as vessel size or type, gear type, fishing effort, etc. In our previous analysis we also did not find any covariation between Steller sea lion survival and ocean productivity or sea surface temperature, which didn’t surprise us because of the lack of an immediate direct link between primary productivity and sea lions.

Refining fishery analysis

Because of the limitations in the original fishery data we obtained, in this year we successfully worked to obtain an updated and verified fishery reports dataset. With this dataset we performed new modeling of the commercial fishery activity in order to incorporate levels of catch per unit effort and compare it with catch density levels. We also compiled the data and summarized it to match our Steller sea lion census data periods.

We built a linear mixed effects model that estimated the relationship between fishery catch levels and vessel size (water displacement), tow time (net operation time), trawl dimensions, tow depth, distance from shore, region, year and month of year. We treated year and region as random effects. The model results highlighted the strong effect of all of these parameters, including an interaction of vessel size and trawl dimensions with catch levels.

For our initial evaluations, we restricted our analysis to mid-size vessels (2000 to 4000 metric tons) using mid-size gear (median trawl opening circumference = 624 m) for pelagic and bottom trawls within 30 nm miles from the coast, which allowed us to make unbiased estimates of fish availability for vessels in different years and regions. We chose a distance of 30 nm assuming that most Steller sea lion foraging trips will not reach further than that distance from shore (Fig. 10). We evaluated catch weight per hour, per vessel, with the fishery fleet that not changed over time. We did this refined analysis for 3 of the main commercial fish species (pollock, Atka mackerel, and Pacific cod) and determined those values in four regions (Western Bering Sea, Eastern Kamchatka, North and South Kuril Islands).

Most of the pollock fishery occurred in the Western Bering Sea (Fig. 10. We did not examine catches in the Sea of Okhotsk, because we did not include any SSL data from that region. Within the Western Bering Sea region there was a clear pattern of variation over time (Fig .11). Between 1996 and 2013 catch per unit effort has displayed at least three peaks and 2 low points. Changes in catch density (metric tons per square km per census year) closely matched the catch per unit effort pattern, but in the decade of the 2000s there was a lag of about one to two years. This delayed response of catch density to changes in fish availability to vessels may indicate some level of over-fishing (Fig. 11).

Eastern Kamchatka, which is located nearby to the Western Bering Sea, had a much lower level of pollock catch. Catch densities were at a minimum in the years 2001 - 2005, opposite of catch changes in the Western Bering Sea. High catch density levels were found around 2009 – 2010, again the inverse of the Western Bering Sea data, where the pollock fishery was at a low level in 2009 - 2010. Since 2005 - 2006 both catch per unit effort and catch densities have constantly increased in the Eastern Kamchatka region. In this region, we did not see the pattern of covariation between the two parameters as we observed in the Western Bering (Fig. 12)

In the Kuril Islands, the pollock fishery catch was at much lower levels than in the Western Bering Sea. As in Kamchatka, it was at minimum levels in the early 2000s. Both catch densities and catch per unit effort started to increase in 2003 in the North Kuril Islands and in 2006 in South Kuril Islands (Fig. 13 and 14).

The majority of the Pacific cod fishery also occurred in the Western Bering Sea. High catch levels were reported there in the late 1990’s. In contrast with the pollock fishery, catch density levels did not vary here since the early 2000s. Catch per unit effort also did not vary greatly over time, but increased in recent years (Fig. 15).

Pacific cod catches in Eastern Kamchatka followed a similar pattern, but catch densities increased greatly in recent years (Fig. 16). In the late 1990’s fishery levels were high in Eastern Kamchatka as well, and declined by the end of 1990s. Catch density levels were at low levels in the early 2000’s but started to increase in 2004. Catch densities increased along with catch per unit effort until 2010. After that catch densities continued to increase and by 2012 reached levels similar to the high values seen in 1996 - 1997. However, catch per unit effort started to decline after 2010 (Fig. 16). This discordance between catch per unit effort and catch density levels may indicate that overfishing most likely occurred in Eastern Kamchatka recent years.

In the Western Bering Sea Atka mackerel catch was at very low levels, and primarily was bycatch to other fisheries. In Eastern Kamchatka, one of the main regions for the Atka mackerel fishery, catch density and catch per unit effort values were at very high levels in late 1990’s (Fig. 17). Catch densities remained at high levels in the early 2000’s, while catch per unit effort dramatically declined. Catch densities declined to their lowest levels in 2007, at which time catch per unit effort started to increase. In the year 2010 both parameters started to decline again (Fig. 17). Atka mackerel catch per unit effort trends and catch density trends may indicate a significant level of overfishing in Eastern Kamchatka.

In the Kuril Islands most of the Atka mackerel fishery occurred in the North Kuril Islands (Fig. 10). For many years the levels of this fishery did not change greatly here. However, in 2007 it increased in both catch per effort unit and catch densities (Fig. 18)

Relationship between fishery catch indices and Steller sea lion survival rates

The only rookeries at which we saw significant time variation in survival was the Commander Islands and Kozlov Cape (Fig. 8 and 9). We evaluated independent estimates of catch effort and catch densities and survival rates in order to determine if variation in catch densities and catch per unit effort may explain variation in Steller sea lion vital rates.

Steller sea lion survival and pollock fishery

The two fisheries regions that are located close to the Commander Islands are the Western Bering Sea and Eastern Kamchatka. Only juvenile Steller sea lion survival rate was highly correlated with the pollock fishery in those regions, but the explanation for this relationship is not clear.

Including the Western Bering Sea pollock catch per unit effort as a yearly covariate significantly improved the survival mark-recapture model, suggesting the importance of that covariate in explaining variation in survival. We found that models that incorporated catch per unit effort in the Western Bering Sea were positively correlated with survival of juveniles. Indeed, low levels of juvenile survival coincided with drops in catch per unit effort, while periods during which catch per unit effort was high coincided with high juvenile sea lion survival. Perhaps there is some cyclical environmental factor that increases the availability of pollock both to the fishery and to Steller sea lions, resulting in coincident increases in fishery catch and Steller sea lion survival.

This pattern may be clearly seen in the Western Bering Sea only because catch levels in that region were at very high levels. Overfishing, however, seems to have eventually occurred there and may also influence the patterns of fish availability. However, we do not have strong evidence that sea lions from the Commander Islands or Kozlov Cape are actually spending significant time in the Western Bering Sea in winter. We have received reports of Steller sea lions around fishing vessels in the Western Bering Sea, but they were mostly males in fall and spring, and there have not been many reports of adult females in this region.

The similarities we found in Steller sea lion survival rate and fishery catch variation may indicate a dependence of sea lions on resources available in that region, and raises the question of what factors may similarly affect availability of fish and sea lion survival. Possibilities that require further investigation are that overfishing may potentially be responsible for these oscillations, or perhaps pollock population dynamics are responsible for the observed fluctuations.

The Eastern Kamchatka pollock fishery recently increased in both catch per unit effort and catch density. Both of these parameters were negatively correlated with juvenile Steller sea lion survival. Linear models predicted a strong effect (high slope in model) of catch densities rather than catch per unit effort. The warning sign is that catch densities increased with time much more than catch per unit effort, indicating a high probability of overfishing in that area.

Steller sea lion survival and other fisheries

The only area where the Pacific cod fishery changed over time during our study period was in Eastern Kamchatka. Similarly to the pollock fishery in that area, catch densities increased much more than catch per unit effort. Also, this rate of increase in catch densities was negatively correlated with Steller sea lion survival rates.

The Atka mackerel fishery dramatically declined over time in Eastern Kamchatka, so the highest levels catch densities occurred there at a time during which we estimated low juvenile Steller sea lion survival. Again, the highest levels of catch were observed during times of relatively low catch per unit effort.

Alarmingly, in the Kuril Islands, where the population has been recovering steadily over the last 2 decades, this summer's (2015) pup counts were down 22.2% on Brat Chirpoev Island, 38.9% on Srednego Island, 35.3% on Raykoke Island, and 7.2% on Lovushki Islands. The only Kuril Island rookery where pup counts did not decrease dramatically in 2015 was Antstiferov Island, the most northerly of the Kuril Islands rookeries. This raises important concerns about how recent changes in environmental factors, including fishing may affect Steller sea lion populations throughout the Russian Far East, and may also have important implications for the Aleutian Islands populations.

Significance of long-term monitoring projects

Our results indicated that vital rates are not constant over time. Even though our models based on average vital rates estimates successfully predicted overall population trends most of the time, understanding fluctuations in vital rates is critical for understanding continued changes in Steller sea lion populations. Changes in survival rates of juveniles at both Kozlov Cape and Medny Island displayed significant covariation with the Pollock fishery catch per unit effort in the Western Bering Sea and were positively correlated. However, we found that pollock catch densities in Eastern Kamchatka were negatively related to survival of juvenile Steller sea lions. High Pollock catch per unit effort in the Western Bering Sea suggests that this area is good for sea lions during those times. The negative covariation between fishing metrics and sea lion survival that we found for Eastern Kamchatka is of concern, and the discordance between catch per unit effort and catch densities may be evidence of significant overfishing along Eastern Kamchatka that affected all the major commercial fish species. Even in the regions where Steller sea lion survival remained constant for a decade, as in the Kuril Islands, it may change very suddenly, as appears to have happened very recently. These recent dramatic declines in pup production emphasize the need for continued population monitoring and exploration of possible causes for these recent changes.

The research we have completed so far does not allow us to clearly demonstrate the effect of the commercial fisheries on Steller sea lions in Far Eastern Russia, but sea lion survival clearly followed some of the changes in the fishery patterns. A complicating factor is that there were significant changes in these fisheries in most of our study regions before the period of our mark-resight data were collected. Furthermore, our Steller sea lion vital rates estimates are only valid through 2011, but some significant changes have occurred in the fishery since then. Therefore, extension of our Steller sea lion vital rates estimates through the present will be a critical next step in our work.

PUBLICATIONS/PRESENTATIONS

Altukhov AV, Andrews RD, Calkins DG, Gelatt TS, Gurarie ED, Loughlin TR, et al. 2015. Age Specific Survival Rates of Steller Sea Lions at Rookeries with Divergent Population Trends in the Russian Far East. PLoS ONE 10(5): e0127292. doi:10.1371/journal.pone.0127292

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Altukhov, A, Andrews R., Gelatt, T., and Burkanov, V. 2015. Age specific birth rates at Steller sea lion rookeries in the Russian Far East. Poster, Alaska Marine Science Symposium. January 19-23, 2015, Anchorage, AK, USA.

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specific survival rates of Steller sea lion between declining Commander Islands and growing Kuril Islands? Poster, 20th Biennial Conference on the Biology of Marine Mammals. December 9-13, 2013. Dunedin, New Zealand.

Burkanov, V., Altukhov, A., Andrews, R., Mamaev, E., Nikulin, V., Permyakov, P., Ryazanov, S., Vertyankin, Calkins, D., Loughlin, T., and Gelatt, T. 2014. Apparent age of first reproduction in Steller sea lions on Russian rookeries. Poster, Alaska Marine Science Symposium. January 20 – 24, 2014. Anchorage, AK.

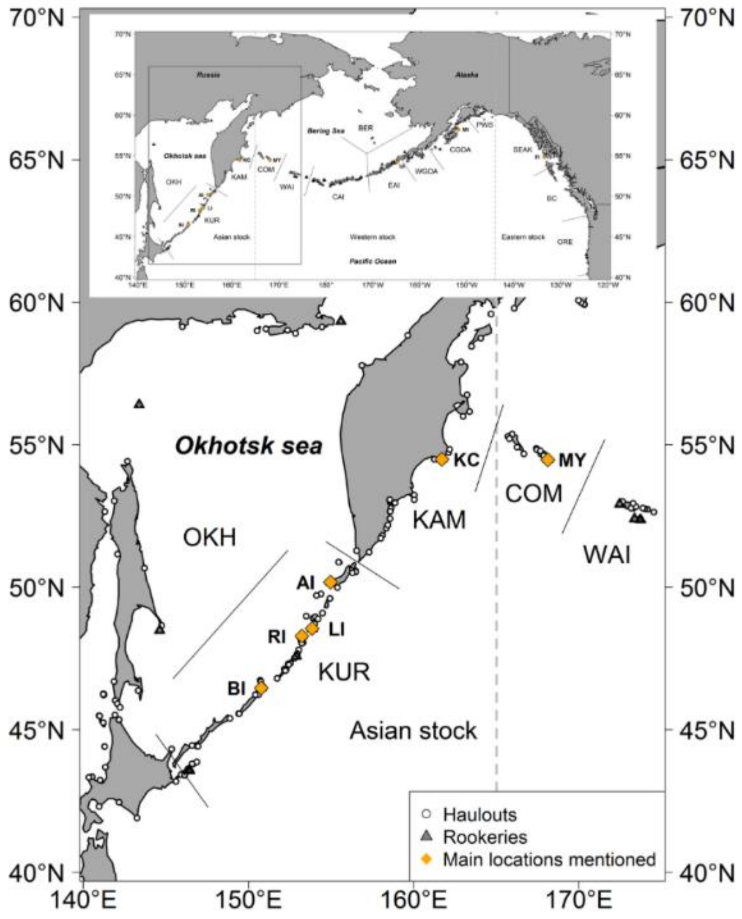

Fig. 1: Steller sea lion terrestrial sites. Study sites: MY = Medny Island, KC = Kozlov Cape, AI = Antsiferov Island, LI = Lovushki Islands, RI = Raykoke Island, BI = Brat Chirpoev Island. Regional designations (after Baker et al. 2005): Sea of Okhotsk (OKH), Kuril Islands (KUR), Kamchatka Peninsula (KAM), Commander Islands (COM), Western Aleutian Islands (WAI), Central Aleutian Islands (CAI), Eastern Aleutian Islands (EAI), Bering Sea (BER), western Gulf of Alaska (WGOA), central Gulf of Alaska (CGOA), Prince William Sound (PWS), Southeastern Alaska (SEAK), British Columbia (BC), Oregon (ORE).

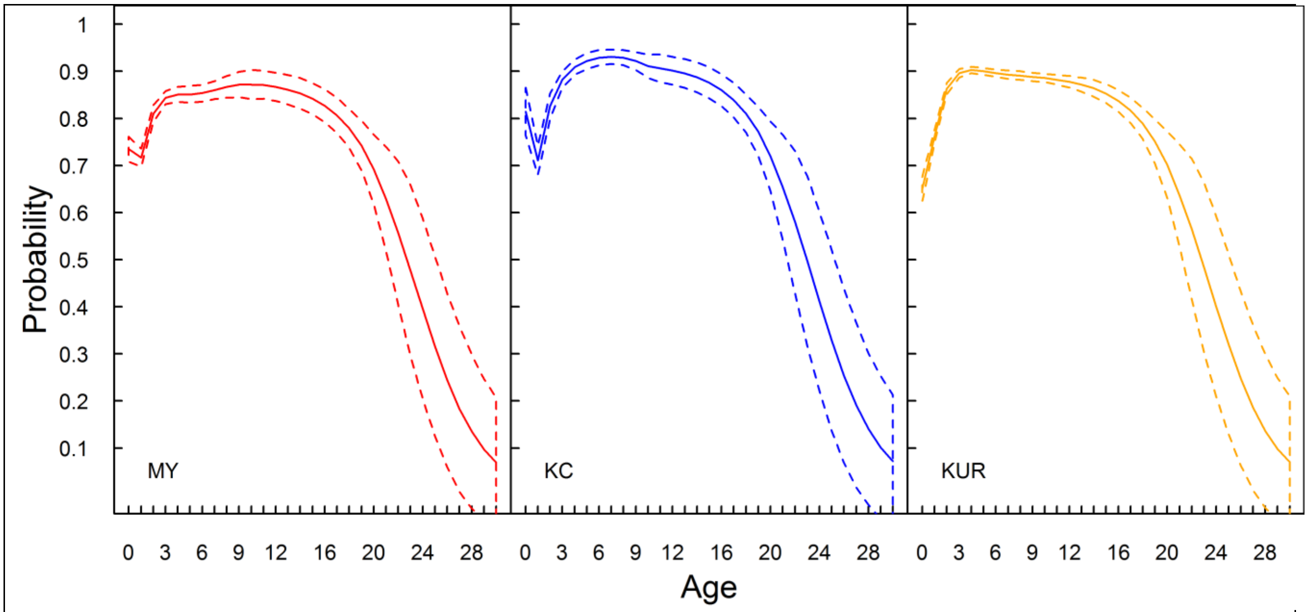

Fig. 2. Extrapolated age specific female survival rates used to build Leslie model matrices. These estimates were based on previously published CJS estimates (Altukhov et al., 2015). Dashed lines = SE.

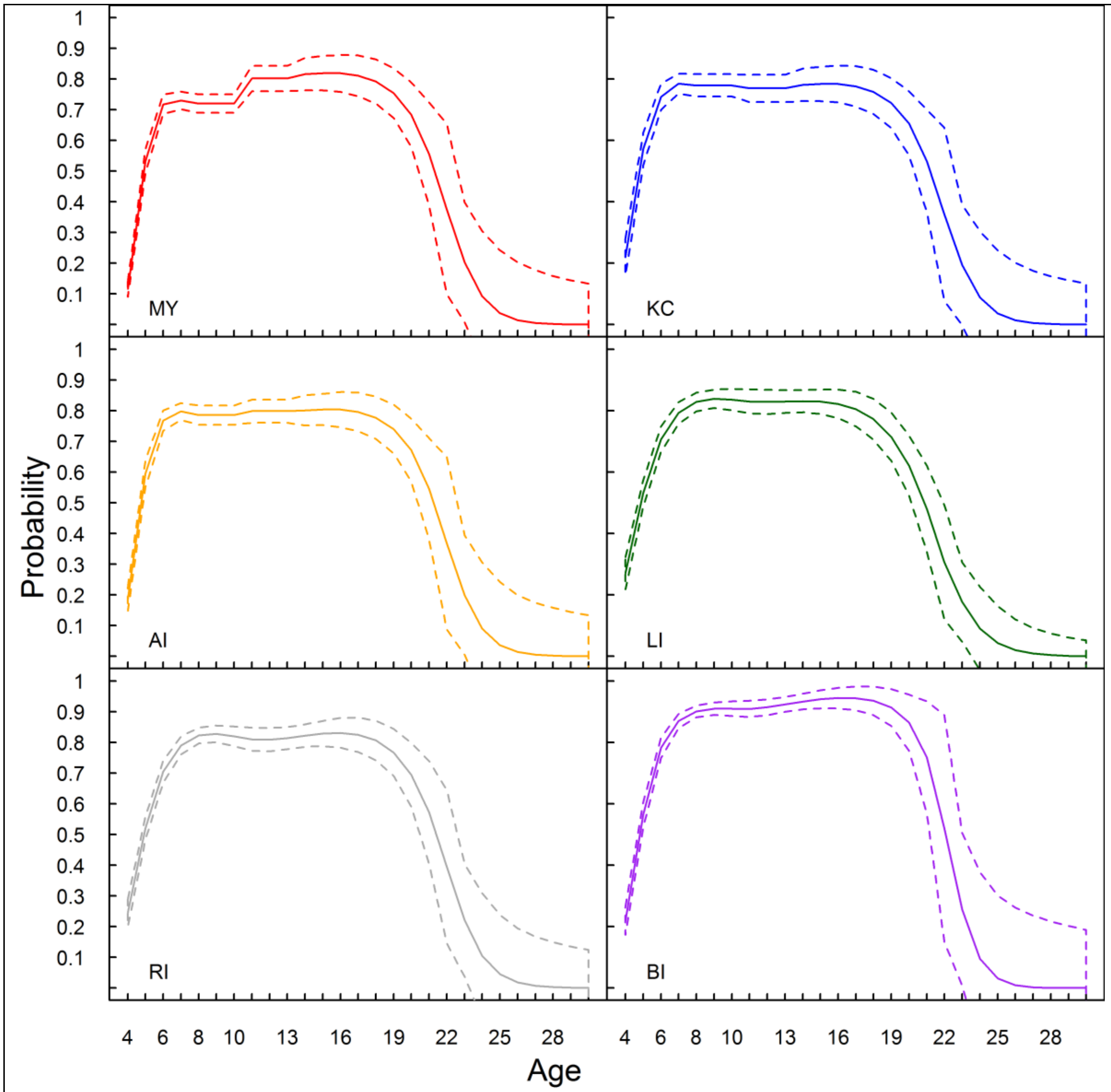

Fig. 3. Extrapolated age specific birth rates used to build Leslie model matrices. MY = Medny Island, KC = Kozlov Cape, AI = Antsiferov Island, LI = Lovushki Islands, RI = Raykoke Island, BI = Brat Chirpoev Island. Dashed lines = SE.

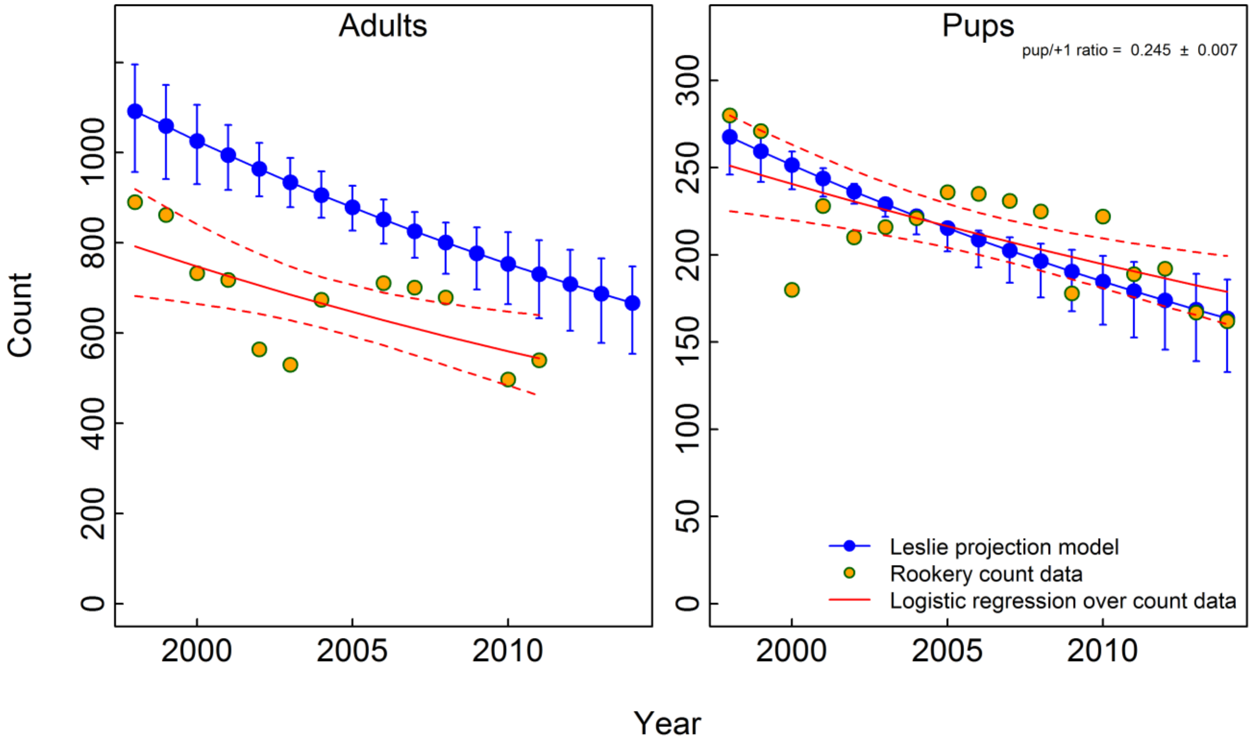

Fig. 4. Leslie population projection model adjusted by rockery pup counts and logistic regression over pup count data in Medny Island. Error bars = 95% confidence interval. Dashed red line = 2*SE.

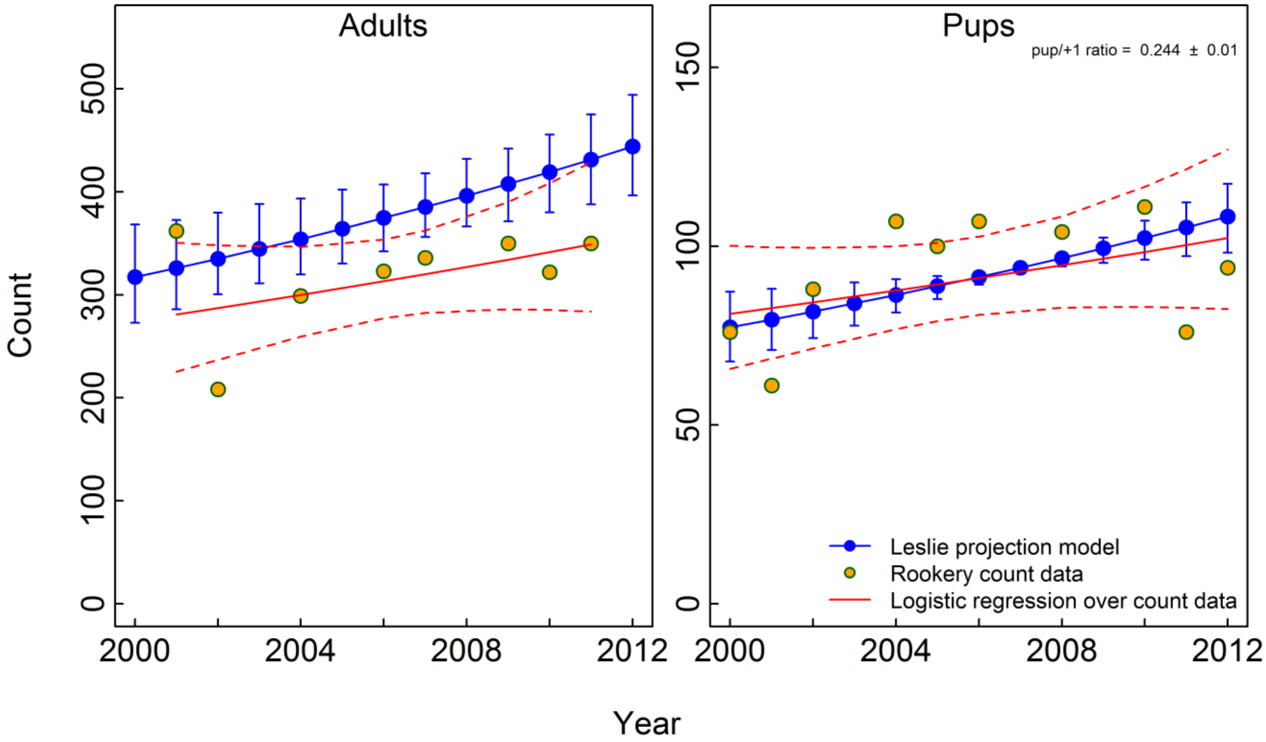

Fig. 5. Leslie population projection model adjusted by rockery pup counts and logistic regression over pup count data for Kozlov Cape. Error bars = 95% confidence interval.

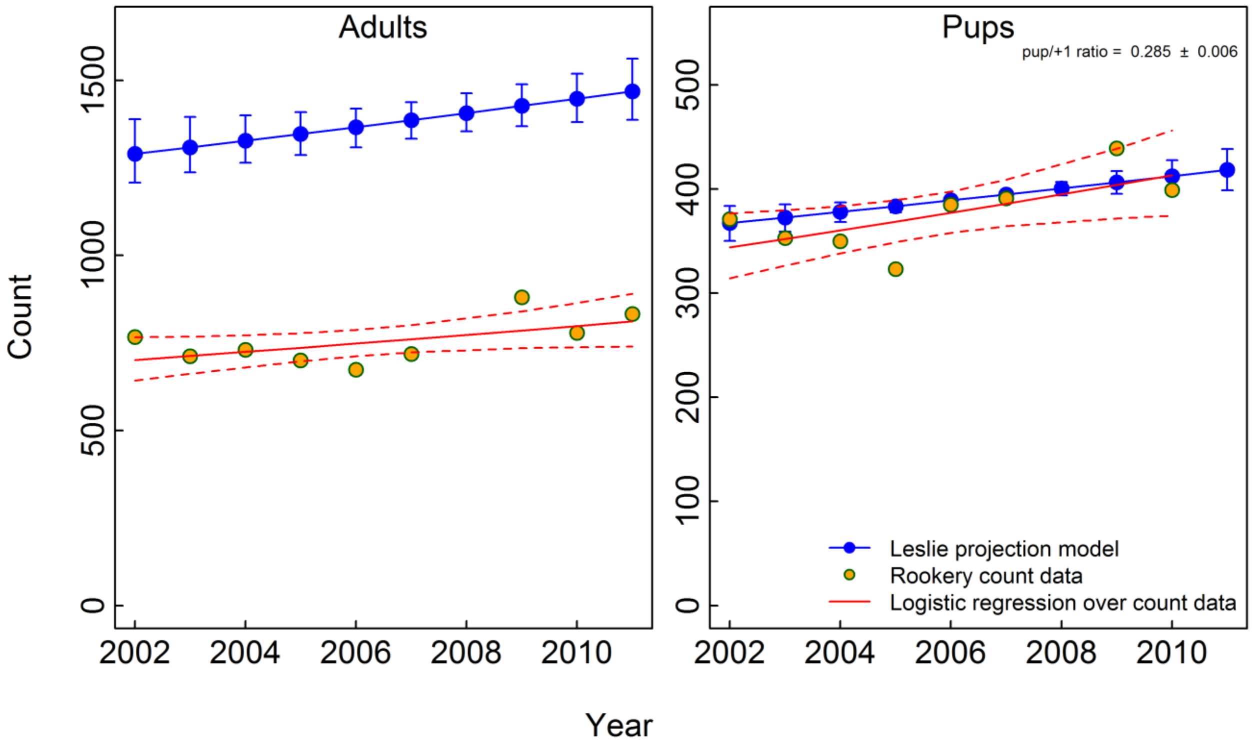

Fig. 6. Leslie population projection model adjusted by rockery pup counts and logistic regression over pup count data in Brat Chirpoev Island. Error bars = 95% confidence interval.

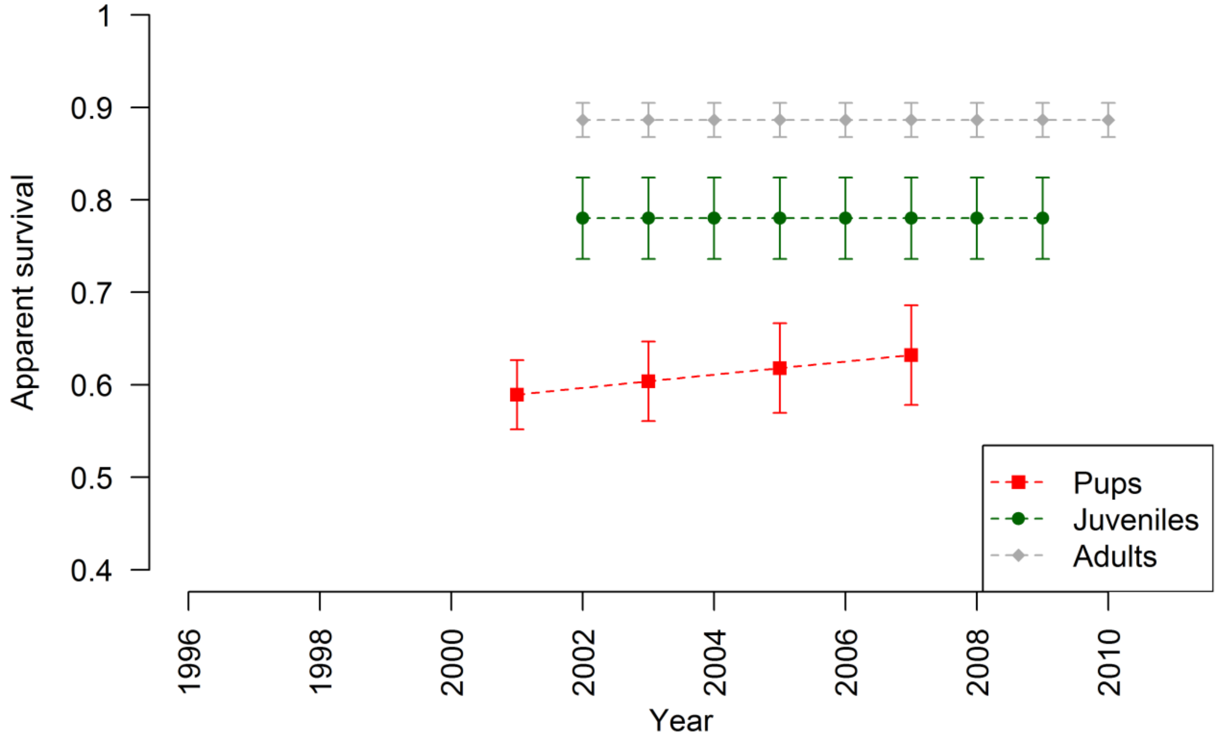

Fig. 7. Survival variation of adult females, juveniles and pups over time in Kuril Islands (Lovushki Islands). Error bars = SE.

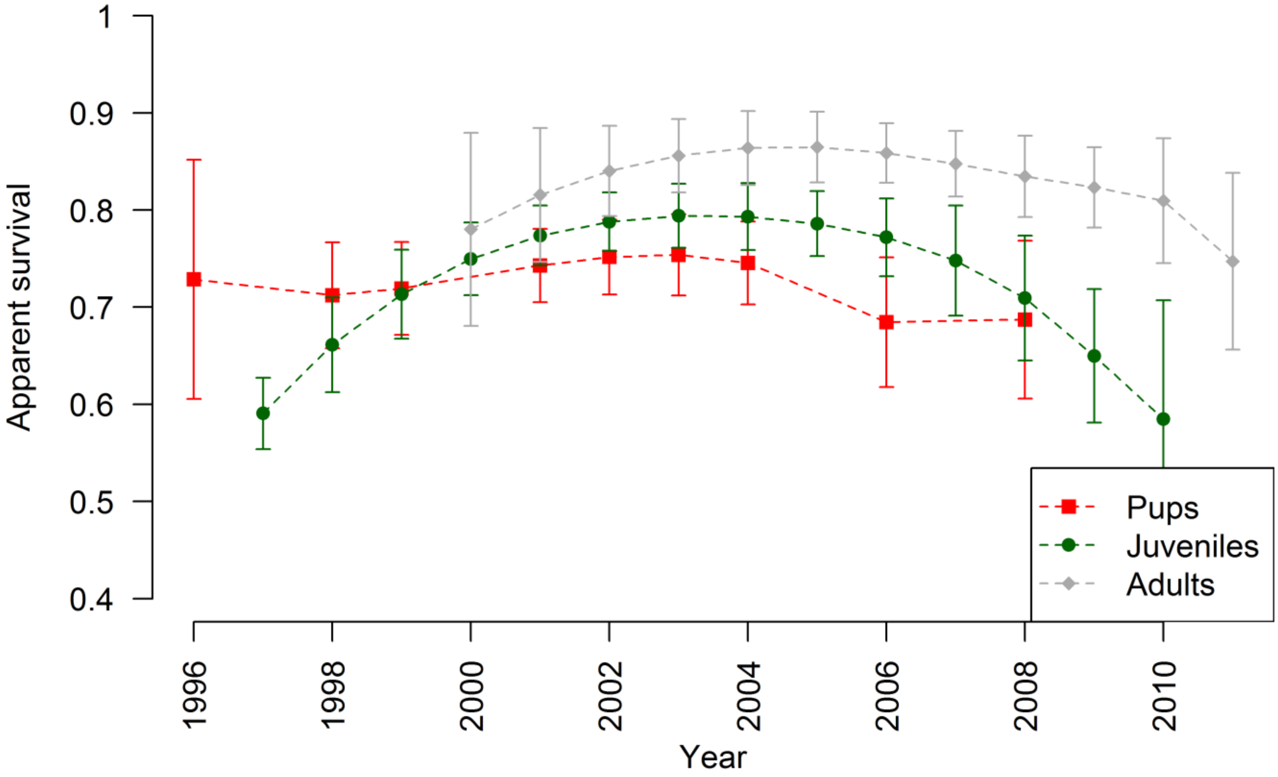

Fig. 8. Survival variation of adult females, juveniles and pups over time on Medny Island. Error bars = SE.

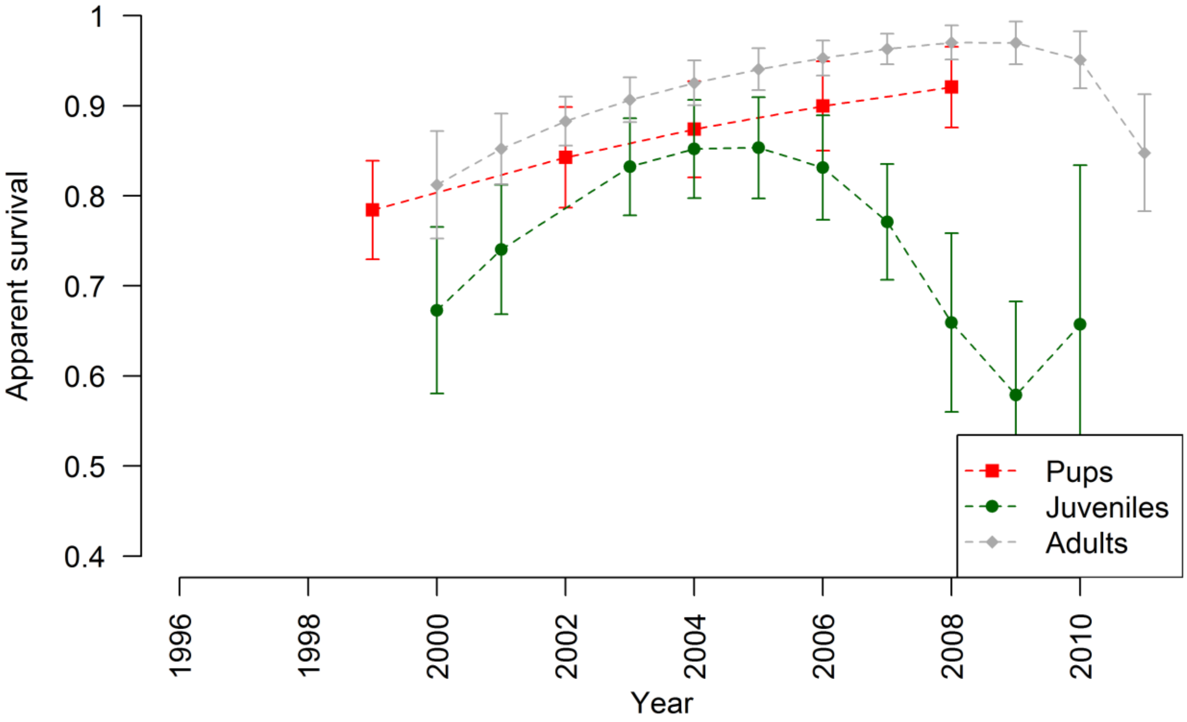

Fig. 9. Survival variation of adult females, juveniles and pups over time at Kozlov Cape. Error bars = SE.

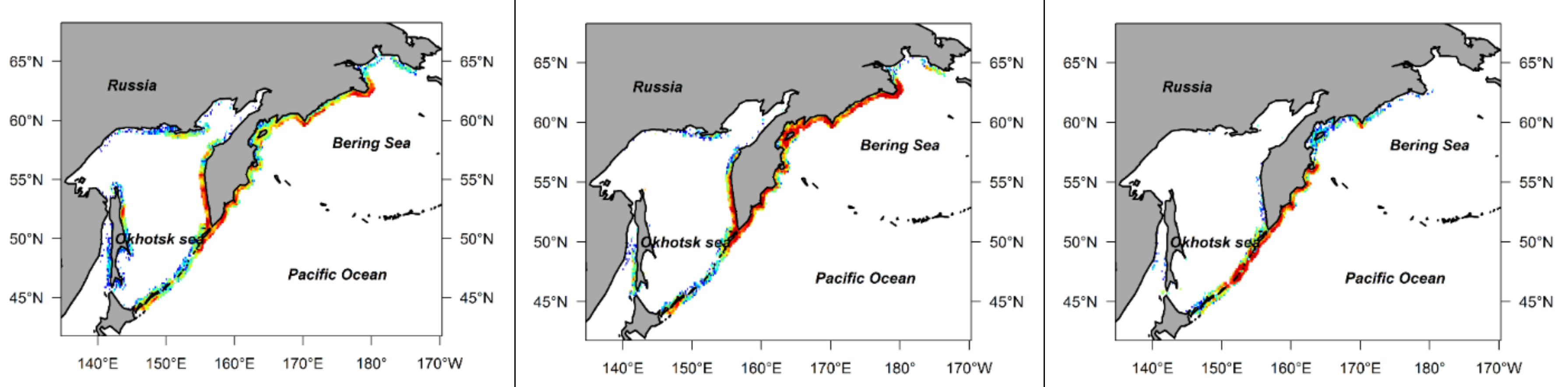

Fig. 10. Average catch density levels within 30 nautical miles from coast line. (Left – pollock, Middle– Pacific cod, Right– Atka mackerel)

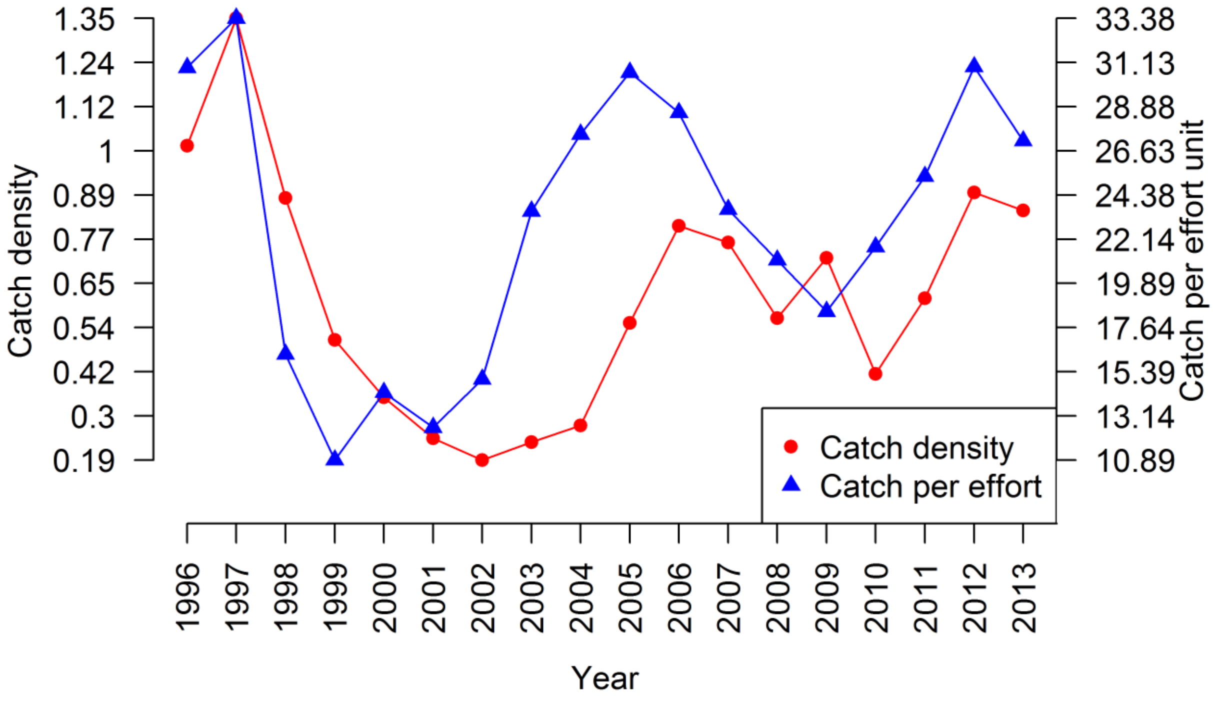

Fig. 11. Western Bering Sea. Pollock catch densities and catch per unit effort within 30 nm from shore.

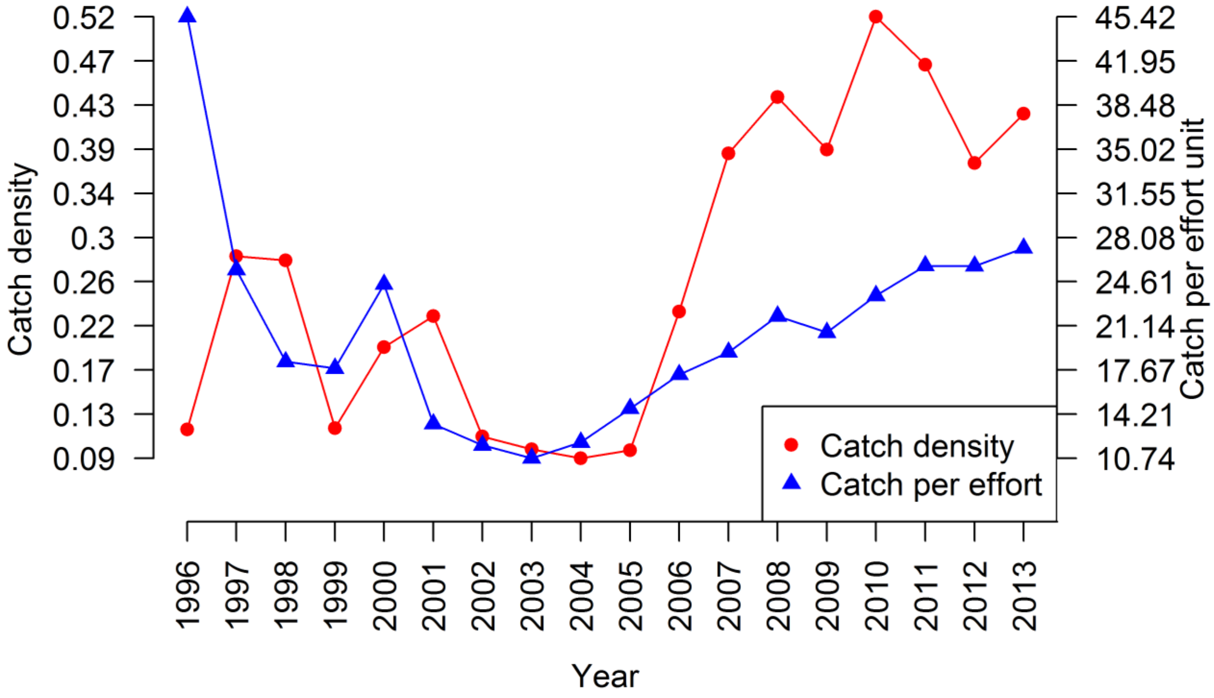

Fig. 12. Eastern Kamchatka. Pollock catch densities and catch per unit effort within 30 nm from shore.

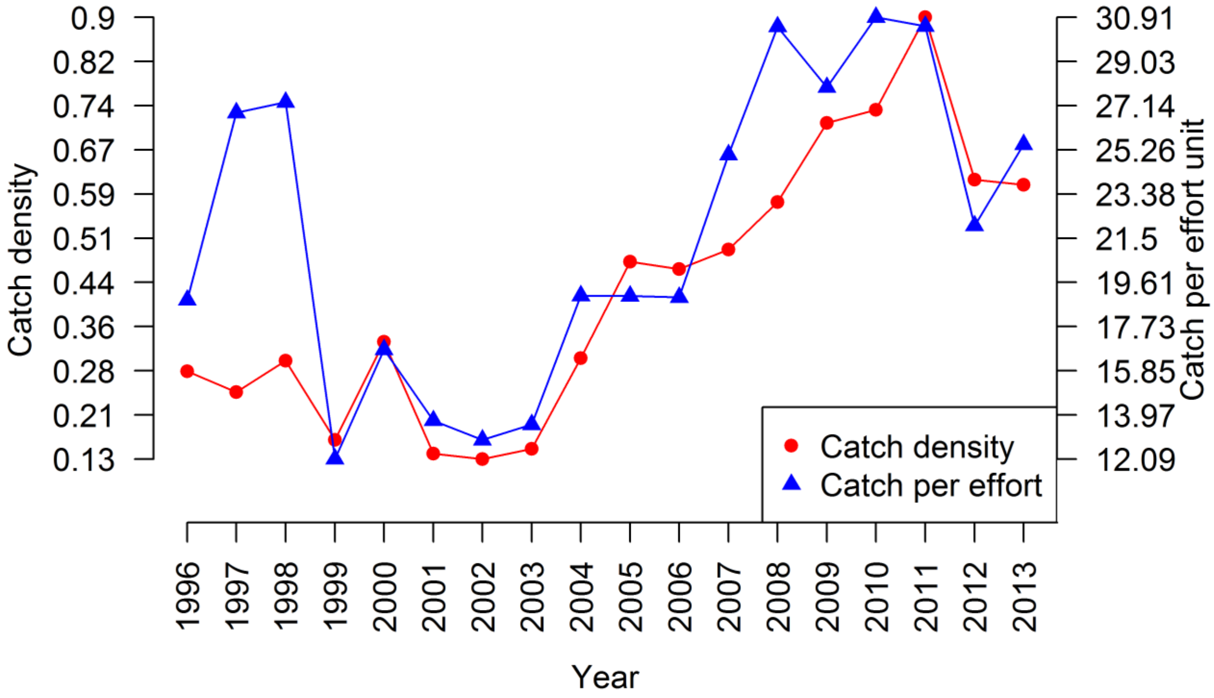

Fig. 13. North Kuril Islands. Pollock catch densities and catch per unit effort within 30 nm from shore.

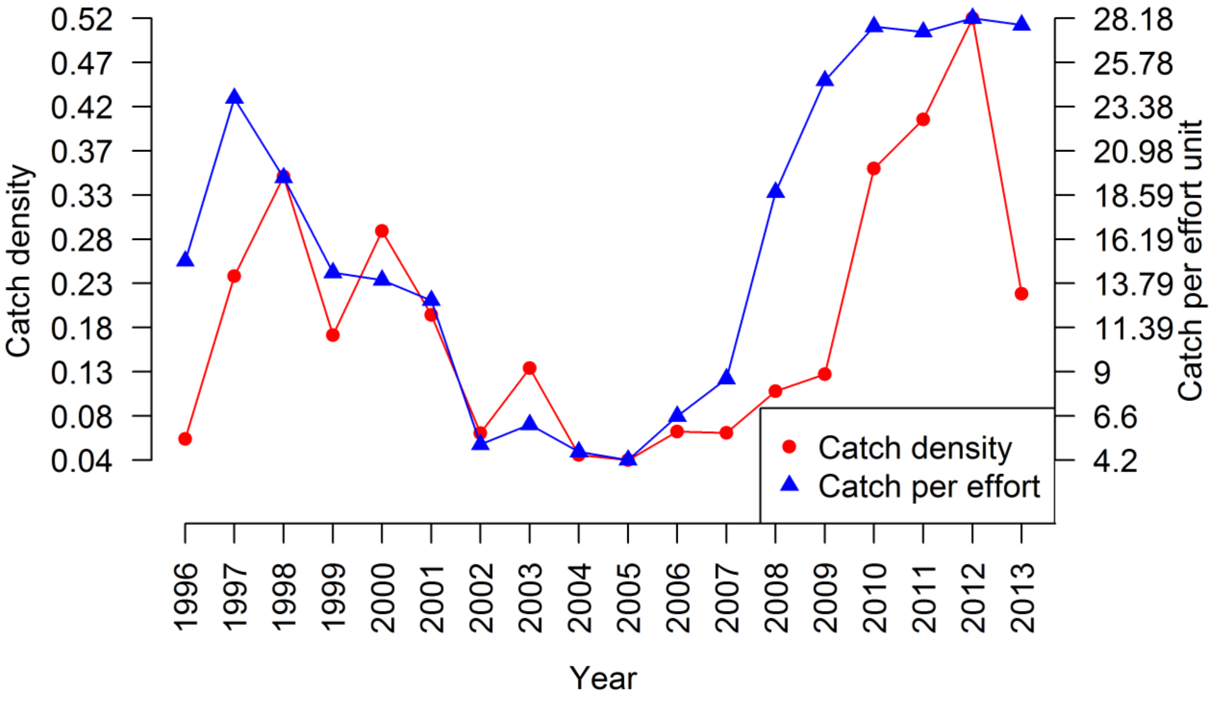

Fig. 14. South Kuril Islands. Pollock catch densities and catch per unit effort within 30 nm from shore.

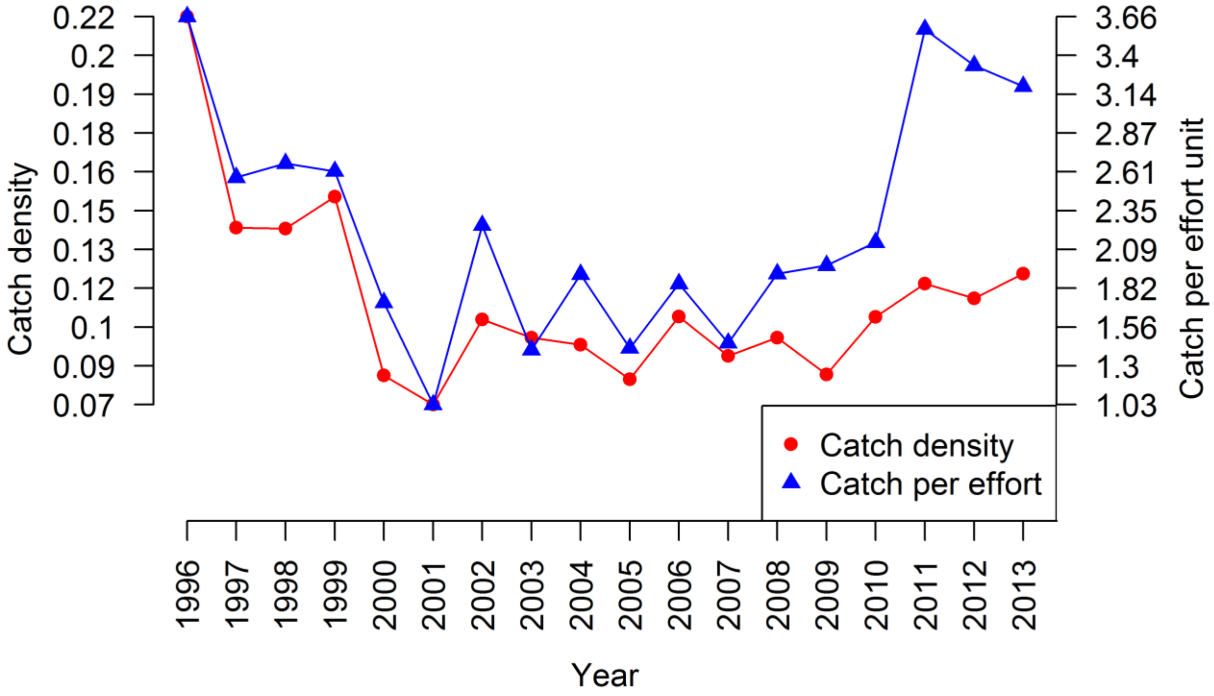

Fig. 15. Western Bering Sea. Pacific cod catch densities and catch per unit effort within 30 nm from shore.

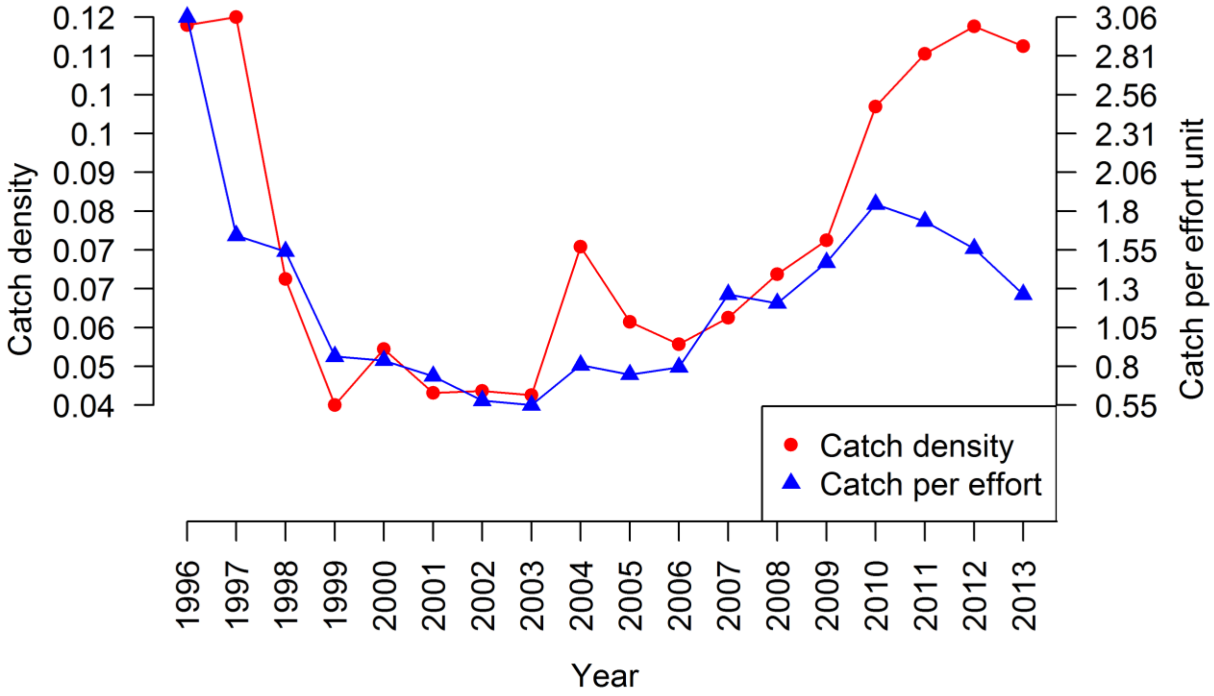

Fig. 16. Eastern Kamchatka. Pacific cod catch densities and catch per unit effort within 30 nm from shore.

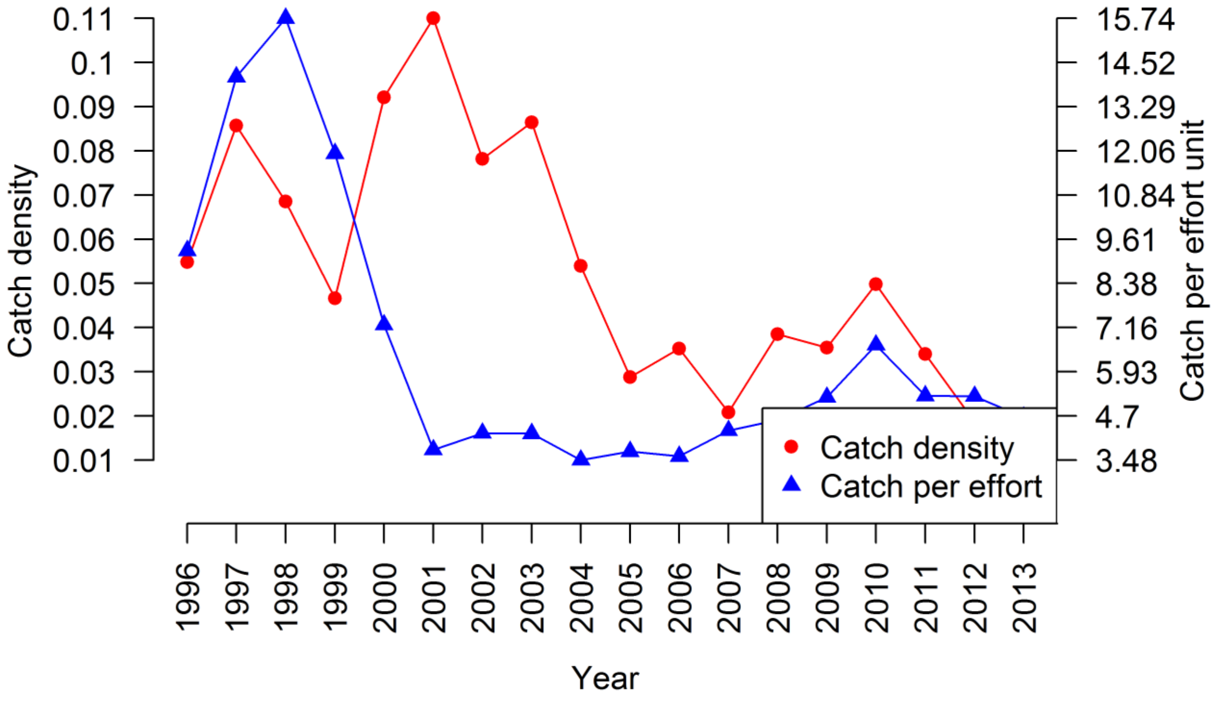

Fig. 17. Eastern Kamchatka. Atka mackerel catch densities and catch per unit effort within 30 nm from shore.

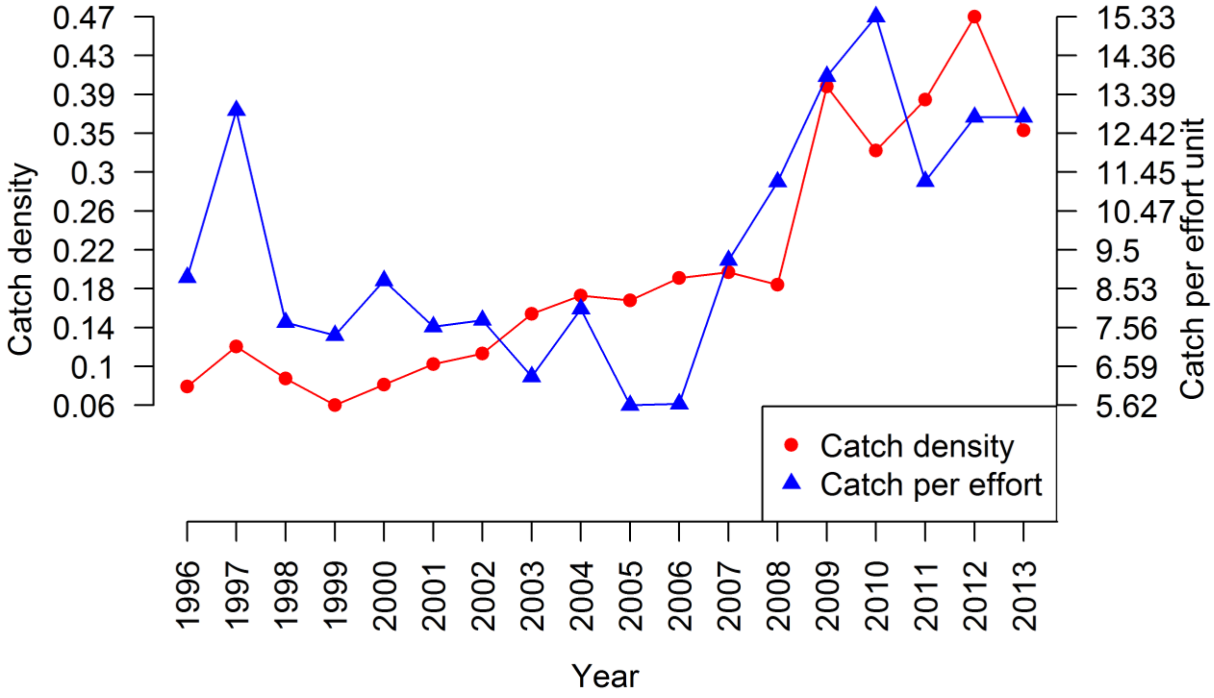

Fig. 18. North Kuril Islands. Atka mackerel catch densities and catch per unit effort within 30 nm from shore.