STELLER SEA LION TELEMETRY STUDIES

A review conducted for the Center for Independent Experts

By

Ian L Boyd

Executive summary

A review of satellite telemetry studies was carried out between 1 and 18 June 2004. This found that the team responsible for Steller sea lion research at the National Marine Mammal Laboratory (NMML) has been at the leading edge of new innovations in the field of marine mammal tracking. The program had been responsible for stimulating early developments in satellite transmitter technology and continues to innovate with the development of new sampling methods. The program is generally using the most up-to-date technology and statistical methods. Areas where new techniques could be applied include: (i) path analysis as a means of smoothing the tracks of sea lions; (ii) simulations to assess the effects of likely sampling biases; (iii) state-space modelling as a way of capturing all the uncertainties about movements into a single analytical framework and; (iv) the integration of movement and behaviour data with data about the population distribution to develop a population-wide estimate of space usage by Steller sea lions. Data from satellite telemetry could also be used to calibrate both mark-recapture studies to estimate vital rates and surveys of the population.

Recommendations

Although not expressly asked to do so, I have provided some recommendations in the text and these are summarised as follows:

- Investments in innovations in capture methods should be continued.

- All efforts should be made to secure all SDR data collected using public funds within this single central database.

- Simulations of the filtering method should be carried out before publication of the manuscript by Robson et al. Consideration should also be given to the implementation of methods of path analysis.

- The group requires more biometrical support in Seattle.

- Steller sea lion studies should abandon the type of sampling of sea lion behaviour involving histograms using 6-h time intervals.

- NMML should begin to develop state-space approaches to the modelling of sea lion distributions.

- NMML should consider how it can combine the current data about foraging patterns derived from satellite telemetry with data about distribution and abundance at haul-outs to derive an estimated distribution for the population as a whole.

1. Introduction

1.1 Details of the requirements of the Review are given in Appendix I. The review was asked to assess:

(i) The appropriateness of the programming and deployment strategy of SDRs on juvenile Steller sea lions;

(ii) The appropriateness of the methods used to retrieve and manage telemetry data obtained from Service Argos;

(iii) Appropriateness of the stage-based filtering algorithm used by the NMML to detect haul-out periods and to evaluate the geometry and velocity of movements at sea;

(iv) Determination of whether potential biases have been adequately identified, and whether appropriate measures of statistical uncertainty have been included.

1.2 A group of experts met the Steller sea lion research team within the National Marine Mammal Laboratory, in Seattle, Washington, during 2 and 3 June 2004. The group was supplied with background materials (Appendix II). It also heard presentations from the team concerning their work (Appendix III). The review group expressed its gratitude to the Steller sea lion research team for the positive and helpful way in which it assisted with the work of the review. Discussions took place with Dr. Tom Loughlin, Jeremy Sterling, Bruce Robson, Kate Call, Michelle Lander, Angie Grieg, Rolph Ream and Dr. Tom Gellatt (from the Alaska Department of Fish and Game).

1.3 This review was conducted alongside Dr Bernie McConnell and Dr Mark Hindell, and I am grateful for the discussion with them.

2. Programming and deployment strategy for satellite-linked data recorders (SDRs)

2.1 The research programme has a history of innovation involving the development and use of SDRs. It was the financial and intellectual driver behind the initial development of SDRs which are the principal tool for tracking marine mammals. There is a continuing culture of innovation at NMML, and this has been applied especially to issues concerning the programming and deployment of satellite tags. Since Steller sea lions are difficult animals to study, the research has faced substantial challenges, especially with respect to the methods used to gaining access to animals.

2.2 The leading role of NMML within the field of marine mammalogy is important to the field. This is especially the case for the Steller sea lion research programme, and the capabilities of this programme and others at NMML provide an important national strategic capability. It is important that NMML should maintain its position of leadership in the field of the development of new basic technologies.

2.3 The programming and deployment strategy for instruments has gone through a process of evolution that corresponds to the development of biological knowledge and logistic and technological capability. Part of the innovation process exhibited by the research team has been to ensure that the most up-to-date technologies are being used.

2.4 Constraints faced by the research team include those imposed by the manufacturer's pre-programming of the satellite tags and design of data collection protocols. Although the Steller sea lion research team has had past input in the design and programming of instruments by the manufacturer, these have been optimised to meet a more general requirement than those associated just with Steller sea lion research. The Steller sea lion team has had little direct control over the programming and design of the tags.

2. 5 A particular constraint has been the system of placing behavioural data into pre-programmed "bins" transmitted as 6-hour summaries. Although this form of data collection was initially designed to overcome constraints associated with low transmission baud rates from the SDRs to the satellite, new systems of data compression and on-board analysis have helped to overcome this constraint to some degree. To maintain a consistent data collection protocol, the Steller sea lion research has continued to use the old data collection routines, but I noted that the Steller sea lion research team's researchers had begun to shift to use of the more up-to-date data collection protocols.

2.6 The reliability, life-span and data flow from the instrument has also improved through time leading to increasing value for money from SDR tools. This has occurred as a result of more informed use of instrument capability, e.g programming during certain periods of the day involving duty cycling to avoid periods of low satellite coverage, changes in the priority of different data streams, such as increasing the priority and frequent reporting of time-line data as opposed to histograms of dive data, and by increasing the total number of transmissions allowed from each instrument per day. Added to this, there have also been improvements in the satellite service. As a result of all these changes, data transmission rates achieved by the Steller sea lion programme have increased progressively, especially since 2000.

2.6 Animal capture strategies have been improved, and this is one area in which the team has shown particularly high levels of innovation. Capture methods have moved from disruptive techniques in the breeding colonies towards scuba lasso techniques and raft traps. As far as I am aware, these methods have not been used elsewhere. This has revolutionised access to animals of different age and sex classes and has the potential to allow the stratification of sampling in order to offset potential biases from the over-sampling of particular age and sex classes. **I recommend that investments in these innovations in capture methods should be continued.**

2.7 Information was provided about the number of SDR deployments that had been made at each site from Washington State through to the western Aleutian Islands and Russia. This is a very large area to cover and, with the resources available, it would be impossible to obtain meaningful samples of different age and sex classes in each of the six main regions of the range of the sea lions. The sample sizes from each region, which covers a total of 32 sites at which deployments have taken place, is as follows:

Region	Total
Central Aleutian Islands	9
Eastern Aleutian Islands	45
Gulf of Alaska	69
Russia	10
Washington	12
Western Aleutian Islands	3
Grand Total	148

2.8 The concentration of effort on the Gulf of Alaska and Eastern Aleutian Islands appears to be a consequence of both greater accessibility than most of the other regions and the importance of these regions as (i) areas in which there has been a rapid rate of decline in the sea lion population and (ii) areas in which there are likely to be the most significant conflicts between management measures for sea lion conservation and the needs of the fishing fleet.

2.9 Considering the constraints on resources and the perceived priority areas the historical pattern of deployment appears to have been logical. Clearly, areas with low coverage, especially the Western Aleutian Islands would benefit from greater coverage. But the degree to which this is necessary depends upon the heterogeneity of behaviour among regions. It is likely that results from those regions where a large number of deployments have taken place can be extrapolated to regions of low coverage. Representative sampling from these regions may be all that is required in order to satisfy the assumption of homogeneity of sea lion behaviour between regions.

3. Methods used to retrieve and manage telemetry data

3.1 The database procedures used by the Steller sea lion research team were examined. This is another area where there is evidence of innovation. Not only is there a well developed protocol for the retrieval of data from ARGOS, including quality control and checking procedures, considerable thought has been put into the structure of the database used for storing and subsequently retrieving data for use in analyses. The review group found that these procedures were carried out to a very high standard and there is potential for the database structures developed by NMML to be used by other groups collecting similar types of data.

3.2 The features of the database that make it particularly strong include a structure that is sufficiently flexible to deal with different data collection platforms, including time-depth recorder (TDR), the binned data commonly transmitted by SDRs, data from SDRs involving location only and environmental data transmitted from SDRs. Inclusion of meta-data about the subsequent use of data (including which data were used in specific publications and documents) as well as scanned information from field data collection forms was a strong feature of the current approach to databasing.

3.3 The database is in the process of moving from Access to Sequel Server. The review group considered that this was a sensible development to ensure compatibility with most forms of analytic software and to improve the capacity to interface the database with web-based tools. The review group noted that NMML was developing a data access policy. NMML should be encouraged to move towards a system providing broad access to data as quickly as possible. It should be noted that the current databasing system allows the selective release of data to stakeholders and the public.

3.4 There appears to be a high level of connectivity between the database and analysis programmes. A demonstration was provided of the way in which overlays of environmental data can be imported quickly into a GIS, together with data from the Steller sea lion database, to examine relationships between sea lion movement patterns and environmental factors.

3.5 The review group also noted a high level of data security with appropriate backup systems in place.

3.6 One of the greatest concerns about the current system and about the data being used by NMML is that it does not constitute all of the information collected about the movement and behaviour of Steller sea lions. NMML have a close partnership with ADF&G which means that some data sharing takes place, but there are other groups collecting Steller sea lion data and any assessments of foraging behaviour ought to include these data sets. This is a situation outside the control of the NMML Steller Sea Lion Research Program, but it is unfortunate that public funds were being used to gather data that could not then be shared amongst the interested parties.

3.7 Although NMML appears to have access to all the data for Steller sea lions in regions that are associated with the imposition of conservation measures, there would be much to be gained from carrying out range-wide analyses of the data. Since NMML clearly has the database capability to hold, secure and curate these data, **I recommend that all efforts should be made to secure all SDR data collected using public funds within this single central database** after the establishment of access agreements with the various stakeholders. This should be viewed as a community database.

3.8 There may be potential for NMML to embrace GRID technologies to improve access to synoptic environmental data.

4. Filtering algorithm used by NMML

4.1 There are substantial levels of uncertainty around the location data produced from satellite telemetry. Since there is a need to define the foraging ranges of Steller sea lions at spatial scales that are small in relation to the level of noise within some of the data, the Research Team has developed an algorithm for increasing the signal to noise ratio of the data. This has concentrated upon the development of a filter that progressively eliminates locations with a low estimate of plausibility. The paper by Robson et al. (Appendix II) describes this algorithm.

4.2 The algorithm is likely to be well suited to this particular problem and it has been developed as an advanced version of the filtering approach that built on previous work by other groups in the field. The logic underlying the filter is basically sound, but the filter suffers from the same disadvantages of other versions in that it involves the progressive elimination of data. It is possible that the algorithm could introduce a spatial bias if there were a relationship between position and location quality. In addition, it is also possible that the filter could eliminate foraging trips which would result in an under-estimation of the amount of time these sea lions spend at sea. This "destructive" approach to data analysis is now somewhat outmoded. However, a positive feature of the filtering is that it places a high weight on locations with a high level of confidence.

4.3 We considered that there was a need to extend the data analysis process in two directions:

(i) Carry out simulations to test the performance of the current algorithm. This could be done by developing simulated vectors of position with differing ARGOS location classes. Simulations of foraging trips could be built around time-line data from the SDRs. The empirical distributions of error determined for latitude and longitude using transmitters monitored at known locations could be used to introduce error into the simulated vector of locations. Application of the filtering algorithm to the modified vector could then allow a formal comparison to be made between the true vector and the vector produced after filtering. It would also be possible to examine the performance of the filter using tracks with different degrees of heterogeneity in directional movement and location quality bias associated with diving activity. **I recommend that this approach is taken before publication of the manuscript by Robson et al.**

(ii) Over the past few years a new family of approaches has been developed to smooth tracks of animals using path analysis[1]. These make use of maximum likelihood and Bayesian statistics and have several advantages over the more traditional filtering methods. The greatest of these is that they make use of all the data but assign a lower weight (or larger potential error) to locations that have high levels of uncertainty. A second advantage is that they can be shown to be efficient at reducing the level of error in movement patterns. Their main disadvantage is that they are complex to implement and the way in which they operate is not immediately obvious. This can reduce their credibility to a critical audience with relatively low belief in

[1] Jonsen, I.D., Myers, R.A. & Flemming, J.M. 2003. Meta-analysis of animal movement using state-space models. *Ecology* 84, 3055-3063
Thompson, D., Moss, S.E.W. & Lovell, P. in press. Foraging behaviour of South American fur seals *Arctocephalus australis*: extracting fine scale foraging behaviour from satellite tracks. *Marine Ecology Progress Series*.

statistics. However, I **recommend that consideration should be given to the implementation of path analysis.**

4.4 There would be advantages associated with pursuing both these options simultaneously for analysing the Steller sea lion data. If simulations using the filtering method show that the method can be efficient at defining the movement patterns of seals in the context of their use of critical habitat, then the simplicity of the method means that it becomes an attractive option for the future. However, it is most likely that the filtering method will not perform well in situations where animals are making frequent changes of direction and where the sampling frequency (defined by the frequency of positions available from the SDR) is close to the minimum that can be used to define these changes of direction. This minimum is likely to be about twice the frequency of the changes in direction.

4.5 Nevertheless, whatever the outcome of the simulations to investigate the filtering algorithm, there will be a need to examine the smoothing approaches – both because they are less sensitive to problems of signal-noise ratio and because the community as a whole will view these as the way forward, and it is important for the analyses concerning Steller sea lions to be seen to be using up-to-date methods.

4.6 However, the Steller sea lion research team does not appear to include the skills of a biometrician who could work alongside the biologists in Seattle to implement this and other types of high-level statistical approaches (see below) to data analysis, and **I recommend that the group requires more biometrical support.**

4.7 The analysis has been constrained greatly by the need to conform to the 6-h sampling blocks imposed by the manufacturer of the SDRs. To say the least, these represent a major problem but the Steller sea lion research programme is stuck with them and had no choice in the past but to accept this constraint. **I recommend that the Steller sea lion studies should abandon this type of sampling.** The approach to linking the 6-h summary of behaviour to position has been to use the best quality location received in each 6-h sample to fix the geographical location of each assessment of behaviour. These assessments include diving behaviour.

4.8 Under the present circumstances, this is probably the best that can be achieved with the data available. However, interpretation of the data has to consider the possibility that bias may exist where sea lions may be making foraging trips of the kind that tend to straddle the boundary between 6-h sampling intervals. It is doubtful if these data provide an unbiased view of the sections of the water column that are most important to Steller sea lions. Because of the likely confounding of feeding events with travel events, it seems likely that distributions of dive depth based on the 6-h summaries will underestimate the most important depths for Steller sea lion foraging. In addition, regional and sex/age differences in dive depth distribution could result from differences in the distance that animals travel from haul-out sites because the 6-h summaries could contain different amounts of travelling versus foraging dives.

4.9 The proportion of data transmitted as time line data has been increased in recent years. These data appear to be much more valuable but 20-40% of time line data may never be received; therefore, careful consideration should be given to the potential for bias in data analysis and interpretation. Biases could arise if the reasons for lack of data transmission are related to location or behaviour.

4.10 The interpretation and analysis of data from SDRs is fraught with difficulties. However, it is important to view these in the general context of the task being placed upon the Steller sea lion research program with respect to its role to provide advice under the Endangered Species Act. It is unlikely that the uncertainties referred to in this section of my report will jeopardise the broad conclusions about the foraging locations and behaviour of Steller sea lions, and they appear sufficient to be able to define critical habitat for this species.

5. Identification of potential biases and statistical uncertainties

5.1 There are four likely sources of bias and uncertainty in the collection of data from SDRs. These include biases and uncertainties from:

(i) instrument design and data collection protocols;

(ii) the extent to which individuals sampled are representative of the sex and age classes in the population or the target group;

(iii) the location of sampling;

(iv) the type of analysis carried out on the data.

5.2 To an extent, discussion of many of the potential sources of bias is contained within the preceding sections of this report, but there is a need to develop methods that integrate across all of the uncertainties within data and to include these uncertainties in the estimates of the foraging distributions of Steller sea lions.

Instrument design and data collection protocols

5.3 An important advantage of using smoothing methods (see 4.3ii) for estimating the tracks of sea lions is that it is possible to express these tracks with the level of statistical confidence around these locations. It is important for NMML to fully understand the error distributions around the ARGOS classifications of location confidence. While I recognise that some of this information has already been collected, it may be important to ensure that there is an understanding of the extent to which this uncertainty varies between individual SDRs of the same design and between SDRs of different design.

5.4 Bias associated with data collection protocols is arguably a greater problem than defining uncertainty in AGOS locations. The constraints of instrument design and the characteristic of the ARGOS system mean that on-board compression of data has to be carried out before transmission. This compression can involve the implementation of pre-conceived models of how the seals behave and it is often difficult to predict the extent to which this will influence the interpretation of data. One of the most obvious examples involves assumptions about foraging diving only occurring when seals dive to >4 m. This can lead to concatenation of dives and it will almost certainly result in underestimates of the extent to which foraging occurs (if there is an assumption that foraging only occurs during diving). Other biases could arise because of duty cycling of transmissions and some of the greatest concerns about bias arise because of gaps in the flow of information to the satellite. If these gaps are caused by non-random distribution of behaviour, it is likely that they will lead to biased estimates of behaviour. New technology used by NMML should go a long way to helping to reduce this particular source of bias, but it will not be completely eliminated.

Representativeness by sex and age

5.5 The development of new catching methods has allowed NMML considerably greater control of the age class of sea lions selected for use in tracking studies. The current studies are focussed on juveniles because of the current hypothesis that it is these age classes that are likely to account for most of the recent population decline.

5.6 NMML and ADF&G have together deployed SDRs on over 260 sea lions. There has been an uneven spread of deployments among different age and sex classes and most of these have been on juveniles. When these are then divided down by region and time of year, sample sizes are reduced, but the statistical power now available from these sample sizes is probably reaching a level where uncertainty caused by differences between individual animals is sufficiently low to allow examination of foraging ranges at a population level.

5.7 Problems with bias are more subject to speculation than to evidence. It is possible that the current catching methods will select for certain types of individuals, e.g. those juveniles that tend to spend more time near haul-out sites or those that are more likely to take bait because they are hungry. The effect of this on the estimation of foraging distribution is unlikely to be significant, and there is little that can currently be done to eliminate or quantify such a bias.

Sample location

5.8 NMML has distributed its tagging effort among 32 sites from Washington State along the Aleutian chain to Russia. Given the occasional long-distance movements of sea lions between sites, and the resulting interchange of animals between sites, it is likely that the spatial distribution of population sampling gives a reasonably accurate, and unbiased, impression of foraging behaviour. Although some differences in behaviour have been observed between regions, these appear to be small. With larger sample sizes it may be useful to include region as a covariate in the estimation of uncertainty around foraging ranges.

Type of data analysis

5.9 The state-space approach is the contemporary method used to include all sources of uncertainty into data analysis. This involves making a statistical fit of the data to an underlying model. Where seals are concerned, and especially where they are central-place foragers that return regularly to haul-out sites as is typical of Steller sea lions, the underlying model of behaviour can be generated by developing a habitat preference function. This function can be built from information such as quantitative data about the environment including bathymetry, bottom type (especially if the seals are benthic feeders), ocean colour, ocean currents and distance from the haul-out. State-space models offer the possibility of assigning to each habitat feature the degree to which it helps to explain the foraging distribution of the seals. **I recommend that NMML should begin to develop state-space approaches to the modelling of sea lion distributions.**

5.10 Understanding the effects of bias and uncertainty requires the development of a model framework within which to investigate the sensitivity of the output to different levels of uncertainty and different types of bias. It would help NMML greatly in its interactions with fisheries managers, and in setting future research priorities, if it were able to use such a framework to illustrate these types of sensitivities.

5.11 Since the ultimate objective of the satellite telemetry research is to examine the foraging distribution of Steller sea lions, **NMML should consider how it can combine the current data about foraging patterns derived from satellite telemetry with data about distribution and abundance at haul-outs [2] to derive an estimated distribution for the population as a whole**.

6. Additional uses of telemetry

6.1 I identified at least two areas of the research that NMML is undertaking on Steller sea lions where the results from satellite telemetry may provide added value to other projects on the same species. These were:

(i) Mark-recapture studies involving branded sea lions are being used to estimate the survival rate. These types of studies are sensitive to sighting bias, and it may be possible to use the information from satellite telemetry (assuming that it is not subject to the same types of bias) to reconstruct the sighting patterns of individuals given particular patterns of observation.

(ii) Satellite tags provide information about the proportion of time that seals spend hauled-out. This could be used to provide a means of factoring up the survey counts of sea lions at haul-out sites to provide and estimate of the total sea lion population.

[2] Matthiopoulos, J., McConnell, B.J., Duck, C. & Fedak, M.A. (2004) Using satellite telemetry and aerial counts to estimate space use by grey seals around the British Isles. Journal of Applied Ecology, 41.

APPENDIX I

Statement of Work

Consulting Agreement Between the University of Miami and Dr. Ian Boyd

May 21, 2004

Background

The NOAA Fisheries Alaska Fisheries Science Center (AFSC), National Marine Mammal Laboratory (NMML), requests a review of the analytical process used by AFSC scientists to delineate Steller sea lion dive and foraging behavior using satellite-linked dive recorders (SDRs). The data are used extensively by NOAA Fisheries to facilitate fisheries management in Alaska and to delineate critical habitat as required under the Endangered Species Act. The telemetry studies have been the focus of recent litigation, and were identified in court as a critical link in the Agency's decisions pertaining to Alaskan fisheries. It is important that Agency scientists use the best analytical methods available, and that their analysis be accepted by the peer community and Agency constituents.

A critical part of the analysis is the determination of the animal's location when foraging; the analysis leading to this determination requires data sorting and assumptions that can be viewed by constituents as equivocal. NMML developed a transmission protocol for SDRs to collect high-quality location data associated with six-hour sampling intervals. A stage-based filtering algorithm was also developed that used surface-timeline data to detect haul-out periods and iteratively evaluate the geometry and velocity of movements at sea relative to predefined threshold values. The filter also considered Argos location class of adjacent locations as a factor in determining which locations to remove. After filtering, locations were sub-sampled at 6, 12 and 24-hour intervals based on Argos location quality, and the effect of sampling design and filter algorithm was assessed using Schoener's ratio of spatial autocorrelation. The AFSC therefore requests an independent review of this analytical process.

General Requirements

The consultant will need to be thoroughly familiar with various remote sensing methods and basic computer programming and will travel to Seattle, WA, to meet with the involved scientists and to review the input data set and the analytical process. The AFSC will provide copies of relevant documents and a description of the analytical framework (see Appendix II).

The consultant shall review the Steller sea lion satellite telemetry data and the analytical procedures used to filter the data focusing on the following issues:

1.The appropriateness of the programming and deployment strategy of SDRs on juvenile Steller sea lions;
2.The appropriateness of the methods used to retrieve and manage telemetry data obtained from Service Argos;
3.The appropriateness of the stage-based filtering algorithm used by the NMML to detect haul-out periods and to evaluate the geometry and velocity of movements at sea; and
4.Determination of whether potential biases have been adequately identified, and whether appropriate measures of statistical uncertainty have been included.

The consultant shall be provided with background material (listed in Appendix II) to assist in addressing the aforementioned issues. NOAA Fisheries shall provide an agenda prior to the meeting at the AFSC.

The consultant shall conclude in a written statement whether the protocols and analyses represent the optimal approach and best analytical procedures for analyzing Steller sea lion satellite telemetry data for the purpose of managing affected Alaskan fisheries.

Specific

The consultant's duties shall not exceed a maximum total of 12 days - several days for document review, two days to attend a meeting at the AFSC, and several days to produce a written report of the findings. The consultant may perform most of the review, analysis, and writing duties out of the consultant's primary location, apart from the meeting, which shall be held at the AFSC. The written report is to be based on the consultant's findings, and no consensus report shall be accepted.

The itemized tasks of the consultant consist of the following:

1.Reading and considering the documents (listed in Appendix II) that provide context and background on the Steller sea lion telemetry issue.

2.Reading and analyzing the draft manuscript on the stage-based filtering algorithm and other documents describing NMML's telemetry data filtering protocol and data analysis.

3.Attending a two-day meeting in Seattle, Washington, from June 2-3, 2004, to discuss the review background material, the input data set, and the analytical process with AFSC scientists. The meeting will be held in Room 2039 of Building 4 of the Alaska Fisheries Science Center at Sand Point.

4.No later than June 18, 2004, submitting a written report[3] that addresses issues 1-4, as detailed in the above General Requirements section. See Annex II for additional details on the report outline. The report shall be sent to Dr. David Die, via email at ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via email at mshivlani@rsmas.miami.edu.

[3] The written report will undergo an internal CIE review before it is considered final.

APPENDIX II

Documents considered during the review

Anonymous (2003) Addendum to the Endangered Species Act – Section 7 Consultation: Biological Opinion and Incidental Take Statement of October 2001. March 31, 3003.

Anonymous (2004) Satellite telemetry and Steller sea lion research. Prepared by ADF&G and NMFS Steller sea lion research programs.

Anonymous (2004) CD containing information relating to the NMFS Biological Opinion on Steller sea lions.

Call, K.A., Fadley, B.S. & Greig, A. Attendance patterns of juvenile Steller sea lions (*Eumetopias jubatus*) in the Gulf of Alaska and Aleutian Islands derived from satellite dive recorders (SDRs). Abstract.

Fadley, B.S., Robson, B.W., Sterling, J.T., Greig, A. & Call, K. (in prep) Immature Steller sea lion (*Eumetopias jubatus*) dive activity in relation to habitat features of the eastern and central Aleutian Islands.

Lander, M.E., Haulena, M., Gulland, F.M.D. & Harvey, J.T. (in press) Implantation of subcutaneous transmitters in the harbor seal (*Phoca vitulina*). *Marine Mammal Science*, in press.

Loughlin, T.R., Perlov, A.S., Baker, J.D., Blokhin, S.A. & Makhnyr, A.G. (1998) Diving behaviour of adult female Steller sea lions in the Kuril Islands, Russia. *Biosphere Conservation* 1, 21-31.

Loughlin, T.R., Sterling, J.T., Merrick, R.L., Sease, J.L. & York, A.E. (2003) Diving behaviour of immature Steller sea lions (*Eumetopias jubatus*). *Fishery Bulletin* 101, 566-582.

Merrick, R.L. & Loughlin, T.R. (1997) Foraging behaviour of adult female and young-of-th-year Steller sea lions in Alaskan waters. *Canadian Journal of Zoology* 75, 776-786.

Merrick, R.L., Loughlin, T.R., Antonelis, G.A. & Hill, R. (1994) Use of satellite-linked telemetry to study Steller sea lion and northern fur seal foraging. *Polar Research* 13, 105-114.

Robson, B.W., Goebel, M.E., Baker, J.D., Ream, R., Loughlin, T.R., Francis, R.C., Antonelis, G.A. & Costa, D.A. (2004) Separation of foraging habitat among breeding sites of a colonial marine predator, the northern fur seal (*Callorhinus ursinus*). *Canadian Journal of Zoology* 82, 20-29.

Robson, B.W., Greig, A., Sterling, J.T. & Fadley, B. (in prep) An integrated approach to programming and flitering data from satellite-lionked dive recorders: applications for habitat conservation of endangered Steller sea lions.

APPENDIX III

Presentation provided by members of the NMML Steller sea lion research programme.

Loughlin:	Background literature provided to reviewers and brief history of the satellite telemetry project.
Sterling:	Disposition of data once received from ARGOS and summary of data management.
Robson:	Filtering algorithm.
Call:	Use of the data.
Lander:	Instruments used and how they are programmed.