REPORTE OF LA QUINTA REUNIÓN DEL ‘COMITÉ INTERNACIONAL PARA LA RECUPERACIÓN DE LA VAQUITA’ (CIRVA-5)

Los miembros del CIRVA agradecen ampliamente el apoyo brindado por la Comisión Nacional de Áreas Naturales Protegidas / SEMARNAT, World Wildlife Fund México y la US Marine Mammal Commission por proveer los fondos necesarios para desarrollar la Quinta Reunión del Comité Internacional para la Recuperación de la Vaquita, organizada en el Hotel Coral y Marina, Ensenada, B.C., México, del 8 al 10 julio de 2014.

Contenido

Resumen Ejecutivo del CIRVA-5

LA VAQUITA SE ENCUENTRA EN PELIGRO INMINENTE DE EXTINCIÓN

La quinta reunión del Comité Internacional para la Recuperación de la Vaquita (CIRVA) fue llevada a cabo en el Hotel Coral y Marina en Ensenada, Baja California en Julio 8 -10 del 2014.

En su reunión del 2012, CIRVA estimó alrededor una población restante de 200 vaquitas. Desde entonces, se ha considerado que alrededor de la mitad han muerto en redes agalleras, dejando menos de 100 individuos en la actualidad. La vaquita se encuentra en peligro de extinción inminente.

SE REQUIEREN REGULACIONES DE EMERGENCIA

A pesar de todos los esfuerzos hechos a la fecha, los datos más recientes muestran que la población de vaquita está disminuyendo a una tasa del 18.5% por año (Fig. 1). La mejor estimación de abundancia actual es de 97 vaquitas de las cuales menos de 25 podrían ser hembras sexualmente maduras. La vaquita se extinguirá, posiblemente en el año 2018, si la captura incidental en redes de pesca no es eliminada inmediatamente. Por lo tanto, el CIRVA **recomienda firmemente** que el Gobierno de México promulgue regulaciones de emergencia estableciendo una zona de exclusión de redes agalleras (Fig. 2) cubriendo totalmente el área de distribución de la vaquita – no solamente el refugio ya existente – empezando en Septiembre del 2014.

LA VIGILANCIA Y EL CUMPLIMIENTO TOTAL ES CRÍTICO

Esfuerzos anteriores de vigilancia en el mar han fallado y la pesca ilegal se ha incrementado en años recientes a lo largo del área de distribución de la vaquita, especialmente por el resurgimiento de la pesquería de otra especie en peligro – la totoaba. Sin embargo, ya no es suficiente con eliminar sólo la pesca ilegal como ha sido recomendado muchas veces en el pasado. Con menos de 100 vaquitas restantes, toda la pesca con redes agalletas debe ser eliminada. Para salvar a esta especie de la extinción, las regulaciones deben prohibir a los pescadores el uso, posesión o transporte de estas redes dentro de la zona de exclusión y esto debe ser acompañado de programas de vigilancia en mar y en tierra. CIRVA **recomienda** que el Gobierno de México proporcione vigilancia suficiente para asegurar que la pesquería con redes agalleras sea eliminada dentro de la zona de exclusión. CIRVA además **recomienda** que todas las herramientas de vigilancia disponibles dentro y fuera de México, sean aplicadas para detener la pesca ilegal, especialmente la captura de totoabas y la comercialización de sus productos.

USO DE ARTES ALTERNATIVOS DE PESCA

CIRVA **reconoce** el esfuerzo llevado a cabo hasta la fecha para desarrollar redes de pesca alternativas al chinchorro, pero se preocupa por la lentitud del proceso de implementación a pesar de la legislación existente. El CIRVA **recomienda** al Gobierno de México acelerar tanto la concesión de permisos, para la pequeña red selectiva de arrastre de camarón, a los pescadores capacitados, como la inversión en la producción de esta arte de pesca de arrastre de tipo pequeño y entrenamiento de los pescadores para utilzar este nuevo equipo. **Recomienda**, además, aumentar los esfuerzos para introducir alternativas a la pesca con redes de agalleras en las comunidades que se verán afectadas por la aplicación de la zona de exclusión.

LA MONITORIZACIÓN CONTINUA ES ESENCIAL

Finalmente, CIRVA **reconoce** el excelente programa de monitorización de vaquita y la investigación asociada. El programa de monitorización debe continuar para determinar si las nuevas medidas de mitigación están trabajando.

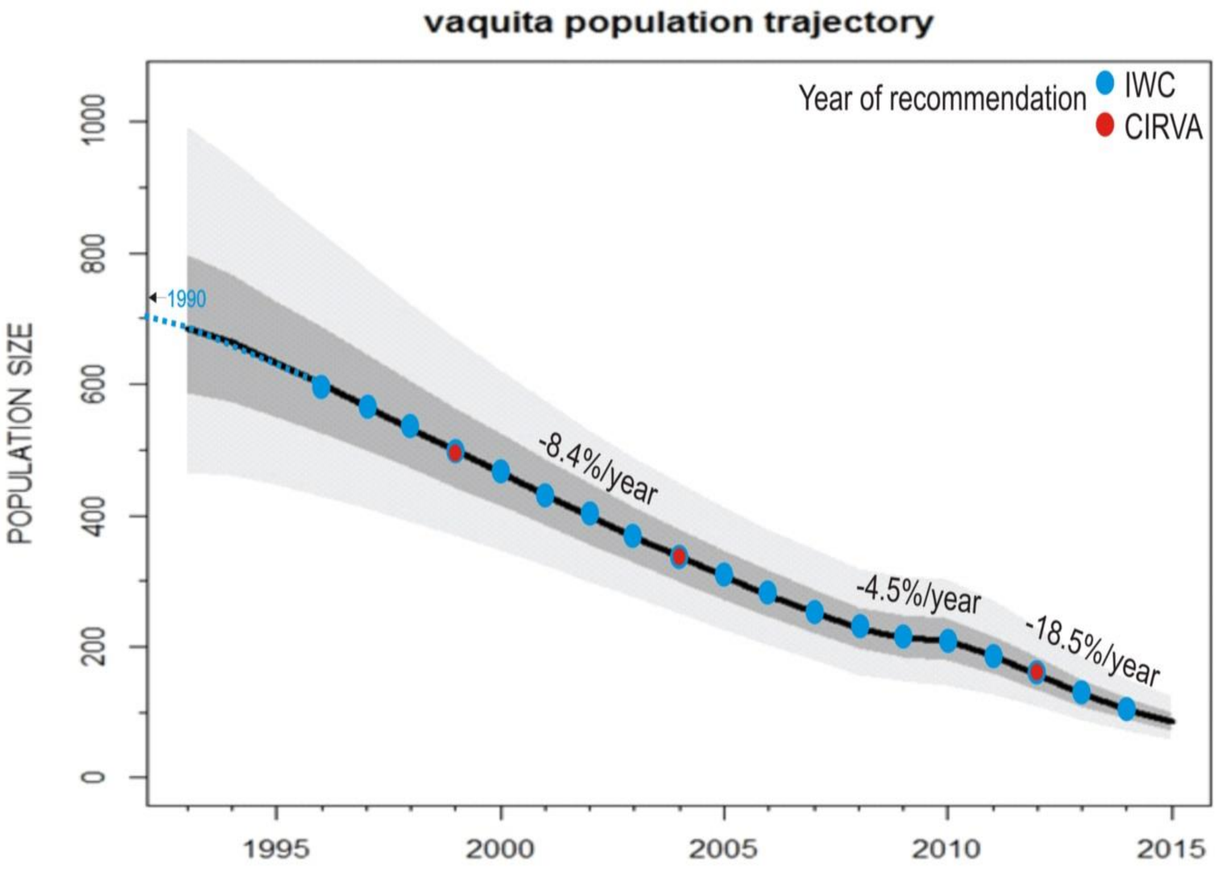


Figura 1. Esta figura indica la trayectoria poblacional de la vaquita. Los puntos azules representan recomendaciones de la Comisión Ballenera Internacional (International Whaling Commission - IWC) y los puntos rojos representan recomendaciones del Comité Internacional para la Recuperación de la Vaquita (CIRVA); ambos el IWC y el CIRVA han recomendado repetidamente que las redes agalleras sean eliminados del área de distribución de la especie (véase también 3.1). Las tasas de disminución fueron obtenidas de Gerrodette y Rojas Bracho (2001) antes del 2010 y de los resultados del Panel de Expertos (Anexo 4) usando los datos acústicos pasivos desde 2011 en adelante. El incremento reciente en la tasa de disminución puede ser atribuida al incremento ilegal de la pesca de totoaba con red agallera.

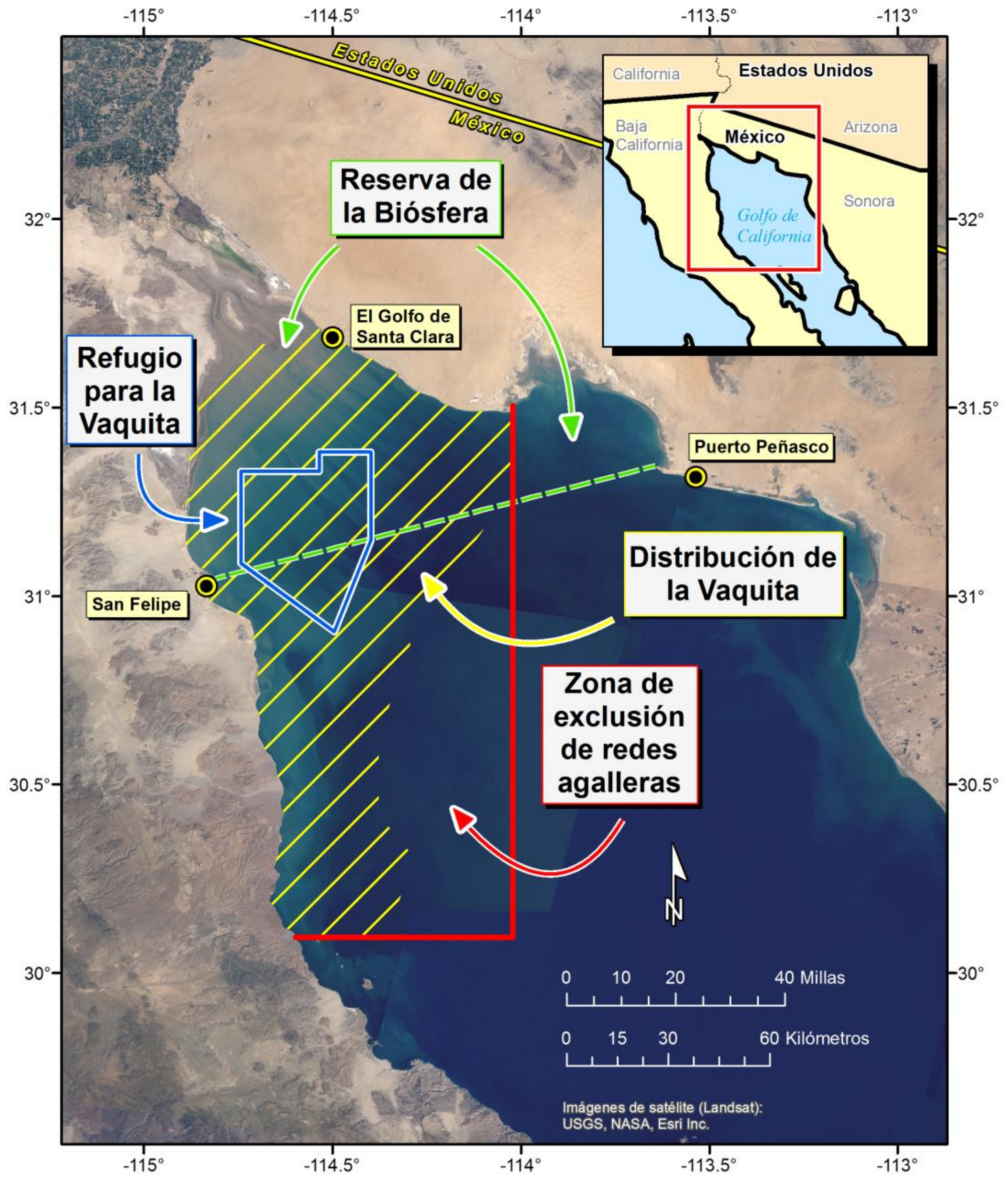


Figura 2. Zona de exclusión de la red de enmalle propuesta en la quinta reunión de CIRVA (al norte y al oeste de las líneas rojas que se intersectan en 30 º 05'42 "N, 114 ° 01'19" W), que contiene todas las detecciones visuales y acústicas confirmadas de vaquitas desde 1990 (líneas amarillas). La zona de exclusión abarca el hábitat crítico para la vaquita, caracterizado por la alta turbidez (apreciable en la imagen satelital) creada por las fuertes corrientes mareales. Para más detalles sobre la distribución de la vaquita ver el Anexo 6. El polígono delimitado por las líneas azules es el Refugio de la Vaquita acordado en 2005. Los límites de la zona de exclusión con redes de enmalle también se eligieron para facilitar su uso por los pescadores y los inspectores encargados de realizar la vigilancia, por medio de una lectura simple de GPS o la ubicación de sitios conocidos en tierra (Punta Borrascosa en el norte y la Isla El Muerto en el oeste).

La Marsopa Mexicana se Acerca a la Extinción: breve declaración sobre su situación actual

La vaquita, una pequeña marsopa que se encuentra solamente en el extremo superior del Golfo de California en México, es uno de los mamíferos más amenazados del mundo. En los últimos tres años, la mitad de la población de la vaquita ha sido matada en redes de pesca, muchas de las cuales son utilizadas ilegalmente para capturar un pez que también está en peligro. Quedan menos de 100 vaquitas y la especie pronto se extinguirá a menos que se tomen medidas drásticas inmediatamente.

La especie fue descrita en 1958 y tiene el área de distribución más pequeña de todas las ballenas, delfines o marsopas. Las vaquitas viven en un área usada intensivamente por pescadores de tres pequeñas comunidades localizadas en las costas del Alto Golfo de California.

Las vaquitas mueren después de enredarse en redes agalleras, también conocidas como chinchorros, utilizadas para pescar escama y camarón. Los chinchorros están diseñados para capturar peces, pero también capturan a otros animales, incluyendo marsopas, delfines y tortugas. El Gobierno de México ha puesto en marcha un plan de conservación para ésta especie el cual incluye un refugio, donde toda la pesca comercial (incluyendo a los chinchorros) está prohibida y un programa para incentivar a los pescadores para cambiar a redes de pesca que no amenace a las vaquitas. Durante los últimos cinco años, el Gobierno invirtió más de $30 millones de dólares en estos esfuerzos que desaceleraron, pero no detuvieron, el declive de la especie. Los científicos han advertido desde hace casi veinte años que cualquier medida menor que la eliminación total de las redes chinchorro podría ser insuficiente para prevenir la extinción de la vaquita.

Una nueva pesquería ilegal ha emergido en los últimos años, la cual representa una amenaza aún mayor para la vaquita. Muchas vaquitas se han matado en lances de redes destinadas a capturar totoaba, un pez gigante que puede alcanzar 2 m de longitud y 100 kg en peso. Este pez también se encuentra en peligro, y es muy valorado por su vejiga natatoria, la cual es usada en China como ingrediente para una sopa y se cree que tiene propiedades medicinales. Miles de vejigas natatorias son secadas y transportadas ilegalmente desde México hasta China, muchas veces a través de los Estados Unidos. El resto del pescado se abandona y pudre en la playa. Los pescadores reciben más de $8,500 por cada kilogramo de vejiga natatoria de totoaba, equivalente a la mitad de la ganancia anual que obtienen a través de las actividades pesqueras legales.

En una reunión llevada a cabo en Julio del 2014, un equipo de recuperación internacional, que asesora al Gobierno de México, advirtió que el tiempo se está acabando rápidamente. A menos que se tomen acciones drásticas inmediatamente, la vaquita se perderá para siempre. Las autoridades mexicanas deben eliminar las pesquerías con chinchorro que amenazan a la vaquita a lo largo del área total de distribución de la especie, y garantizar el cumplimiento de esta medida. El Gobierno también debe detener la pesca ilegal de totoaba. Los Gobiernos de Estados Unidos y China deben ayudar a México para eliminar el comercio ilegal de productos de totoaba. A menos que estos pasos sean tomados de manera inmediata, la vaquita seguirá el camino del delfín del Rio Yangtze y se convertirá en la segunda especie de ballena, delfín o marsopa llevada a la extinción en la historia de la humanidad.

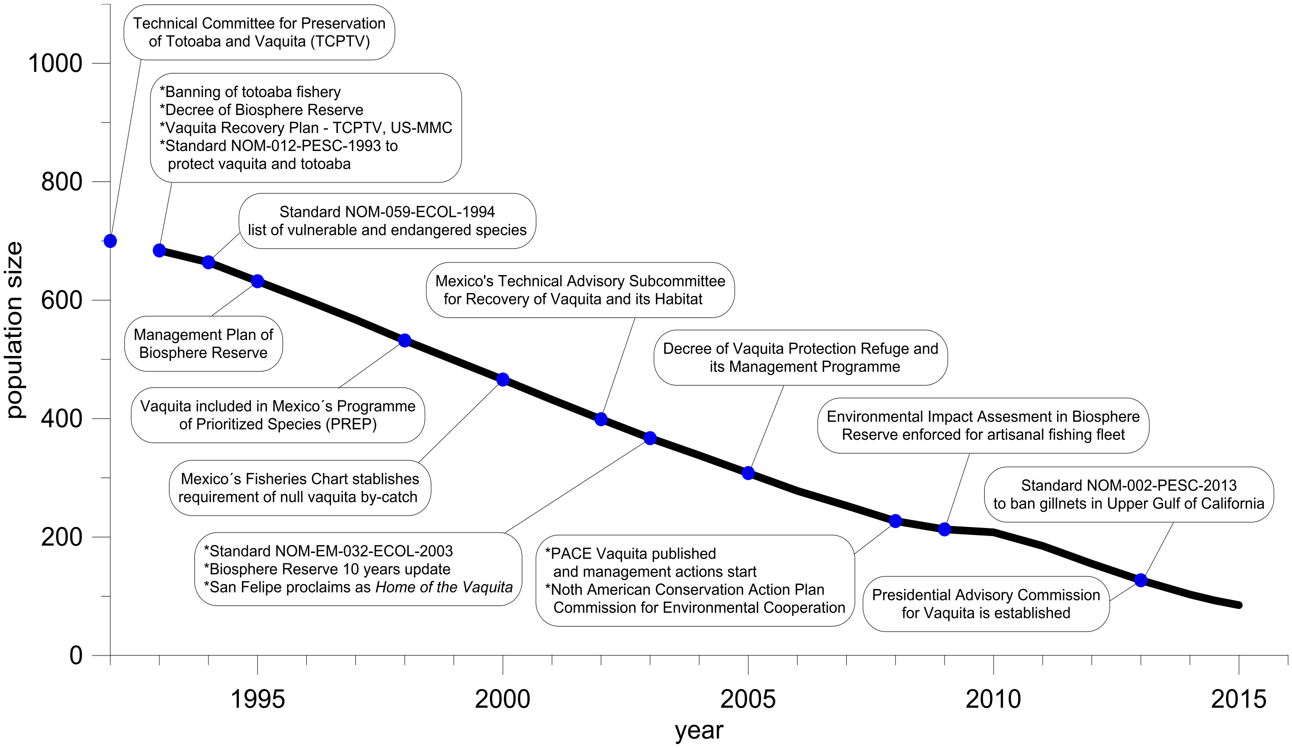


Figura mostrando la disminución de la población de vaquita y las medidas de manejo

1. Introducción

La quinta reunión del Comité Internacional para la Recuperación de la Vaquita (CIRVA) se llevó a cabo en el Hotel Coral y Marina en Ensenada, Baja California del 8 -10 de julio del 2014. Lorenzo Rojas-Bracho dio la bienvenida a los participantes y agradeció a CONANP, WWF y a la Comisión de Mamíferos Marinos de Estados Unidos (U.S. Marine Mammal Commission) por el apoyo otorgado a la reunión.

Atendieron la reunión los siguientes miembros del CIRVA: Lorenzo Rojas-Bracho (presidente) Oscar Ramírez, Armando Jaramillo-Legorreta, Barbara Taylor, Jay Barlow, Arne Bjørge, Peter Thomas, Andrew Read, Robert Brownell, Greg Donovan y Randall Reeves.

Gerrodette, quien es miembro del CIRVA desde hace muchos años no pudo asistir a la reunión, pero contribuyó directamente con los trabajo del comité sobre abundancia de vaquita (ver inciso 2.3 y Anexo 3). Un número de expertos invitados proporcionaron apoyo mediante presentaciones y contribuyendo a las discusiones. Rojas-Bracho presidió la reunión y Read, Thomas y Donovan se desempeñaron como relatores con asistencia de Reeves.

La lista total de participantes de la reunión es brindada en el Anexo 1. La agenda se encuentra en el Anexo 2

2. Tendencia y Estado Poblacional de la Vaquita

2.1 MONITORIZACIÓN ACÚSTICA

La información sobre el programa de monitorización acústica y el análisis de los datos obtenidos en el periodo 2011-2013 (véase también 2.1.1) fue revisado extensivamente primero por parte del Comité Directivo de Monitorización Acústico (véase también 2.1.2) y después por un Panel de Expertos (véase también 2.1.2) antes de ser considerado por el CIRVA.

2.1.1 Reporte del Programa de Monitorización Acústica

Jaramillo-Legorreta dio una reseña breve sobre la historia del programa de monitorización acústica desde su inicio en 1997 hasta el presente. El programa de monitorización actualmente emplea detectores de ecolocalización autónoma (C-PODs) en 48 sitios dentro del Refugio de Vaquita entre Junio y Septiembre, cuando el esfuerzo pesquero en la región es relativamente bajo y por lo tanto se minimiza el riesgo de pérdida del equipo.

Posteriormente, Jaramillo-Legorreta presentó el reporte del progreso del programa de monitorización acústica, el cual incluyó resultados de los primeros tres años de muestreo (2011 – 2013) y un análisis inicial de los datos. Esto incluyó un análisis sobre los cambios en la tasa de encuentros acústicos, el cual fue utilizado como índice de tendencia poblacional. El reporte completo del progreso se adjunta como Anexo 7.

Los datos disponibles provienen de la colocación de 127 C-POD y 9,817 días de muestro en los primeros tres años de monitorización, los cuales generaron 6270 encuentros. La ecolocalización de vaquita fue detectada más frecuentemente en la porción sur del Refugio.

Este reporte se presentó ante el Comité Directivo de Monitorización Acústico (véase también 2.1.2).

2.1.2 Reporte del Comité Directivo de Monitorización Acústica

Posteriormente, Jaramillo-Legorreta presentó el reporte de la segunda reunión del Comité Directivo para el Programa de Monitoreo Acústico de Vaquita, la cual fue convocada en Abril del 2014 para dar revisión a los primeros tres años del Programa de Monitoreo. El reporte de esta reunión se adjunta como Anexo 4. El Comité Directivo concluyó que el Programa de Monitoreo ha funcionado y ha generado datos de alta calidad, y que el desempeño del equipo a cargo del monitoreo ha sido excepcional.

El Comité Directivo concluyó que resultados preliminares del Programa de Monitoreo indicaron que la población de vaquita está disminuyendo a una rápida tasa y que acción inmediata es necesaria para salvar a esta especie. Sin embargo, para confirmar estos resultados, el Comité Directivo ha convocado un Panel de Expertos (véase también 2.1.3) con la finalidad de acordar sobre: (1) la mejor medida de detecciones acústicas y (2) la mejor estimación de tasa de cambio a partir de 2011-2013 usando solamente datos acústicos.

2.1.3 Reporte del Panel de Expertos

El Panel de Expertos se reunió en Junio del 2014 para revisiar los resultados del Programa de Monitorización. El panel consistió en 6 expertos en modelación, incluyendo dos del Comité Directivo de Monitorización Acústico de Vaquita (Jaramillo-Legorreta y Barlow) y cuatro expertos, reconocidos globalmente, en estadística espacial y análisis de tendencias poblacionales. El reporte del Panel de Expertos se adjunta como Anexo 9.

El Panel de Expertos consideró que el programa de monitorización es sólido, pero también notó que el análisis fue complicado debido a la pérdida de algunos C-PODs en 2011 y números bajos de grabaciones en muchos de los C-PODs en 2013. Se desarrollaron varios enfoques analíticos para tomar en cuenta el muestreo irregular; todos indicaron disminuciones sustantivas del tamaño de la población. El Panel acordó en que la variación de año con año en la proporción de vaquitas presentes dentro del área de monitorización podría no ser tomada en cuenta con solo tres de los seis periodos de muestreo completados, pero que es muy posible que esta especie críticamente amenazada continúe disminuyendo a una tasa alta.

El Panel de Expertos generó una estimación independiente de la tasa de disminución de la población de 2011 a 2013 usando datos de encuentros acústicos provenientes del Programa de Monitorización. La mejor estimación de esta tasa de disminución fue de 18.5% por año, un valor mucho más alto que cualquier tasa de disminución reportada previamente para vaquitas. El Panel encontró una probabilidad muy alta (88%) de que la tasa de encuentros acústicos ha disminuido durante el programa de monitorización, con una fuerte probabilidad (75%) de que la tasa de disminución ha sido de más de 10% al año.

2.1.4 Conclusiones del CIRVA

CIRVA **concordó** con las conclusiones del Panel de Expertos y **reconoció** los esfuerzos el equipo de monitorización acústica. También que su programa ha generado una de las imágenes más completas sobre distribución y abundancia relativa para cualquier mamífero marino en peligro de extinción. También **acordó** en que los análisis presentados por el Panel de Expertos (arriba) representan la mejor estimación presente sobre la tasa de disminución de la vaquita entre 2011 y 2013 de 18.5% anual.

2.2 EL FUTURO DEL PROGRAMA DE MONITORIZACIÓN ACÚSTICA

Además de la red de muestreo usual, cinco C-PODs más fueron situados en la porción sur del área de monitorización en 2014. Este será el cuarto año del Programa de Monitorización dentro del Refugio de la Vaquita. CIRVA **acordó** con las conclusiones del Panel de Expertos en que el Programa de Monitorización dentro del Refugio está trabajando como se planeó. El CIRVA **recomienda** firmemente que este programa continúe indefinidamente, con un fuerte apoyo financiero, con la finalidad de determinar si los esfuerzos de mitigación están siendo efectivos.

Jaramillo-Legorreta reportó el problema que ha surgido al tratar de muestrear en las boyas que delimitan el Refugio de Protección. Hasta ahora cuatro diferentes técnicas de anclaje han sido probadas; sin embargo, en todos los casos la mayoría de los detectores se perdieron o fueron robados. CIRVA concluyó que la información obtenida por detectores acústicas colocados en boyas tendría un valor marginal. Por lo tanto, CIRVA **recomienda** que todos los esfuerzos para instalación de C-PODS en el perímetro de las boyas sean abandonados, y que en su lugar haya fondos asignados para permitir al personal del proyecto para recupera, reparar y sustituir detectores dentro del refugio, conforme sea necesario, a los largo de la temporada de muestreo para maximizar el tamaño de muestreo y evitar los vacíos en la información.

2.3 ESTADO ACTUAL DE LA VAQUITA

Taylor presentó los resultados del análisis llevado a cabo por Tim Gerrodette, en el cual se estimó el tamaño de la población de vaquita a mediados del 2014. Detalles del análisis de Gerrodette se presentan en el Anexo 3. Esta proyección empleó la tasa de disminución reciente de los encuentros acústicos estimada por el Panel de Expertos (18.5% por año). Este enfoque tiene el supuesto de que los encuentros acústicos son directamente proporcionales al tamaño de la población dentro del área monitorizada, y de que la abundancia dentro del refugio es proporcional al tamaño total de la población. CIRVA acordó que estos supuestos eran razonables.

Este enfoque muestra que usando la información más reciente (véase también 2.1.3), la mejor estimación de abundancia actual de vaquita es de 97 animales. Esto significa que probablemente existan menos de 25 hembras sexualmente maduras.

CIRVA **aprueba** el enfoque de Gerrodette y acuerda que su análisis representa la mejor evaluación sobre el estatus del estado poblacional de la vaquita.

2.4 CONCLUSIONES Y RECOMENDACIONES DEL CIRVA

A pesar de todos los esfuerzos llevados a cabo hasta la fecha, la población de vaquita está disminuyendo en un 18.5% por año, la especie ha sido posiblemente reducida a menos de 100 individuos (ver CIRVA-4) y la vaquita se extinguirá posiblemente en el 2018, si la captura incidental por pesca no es eliminada inmediatamente (Fig. 1). CIRVA ve esta nueva evidencia con una gran preocupación, y recomienda firmemente que el Gobierno de México promulgue regulaciones de emergencia estableciendo una zona de exclusión de redes agalleras (Fig. 2) empezando en Septiembre del 2014.

Justificación para el área de la zona de exclusión es dada en el Anexo 6. El CIRVA considera que esta especie se puede recuperar, pero solamente si la captura incidental es eliminada inmediatamente. CIRVA notó que otras poblaciones de mamíferos marinos se han recuperado a partir de números muy bajos, incluyendo a los elefantes marinos que fueron protegidos por México en 1922.

Esfuerzos anteriores de vigilancia en el mar han fallado, y la pesca ilegal se ha incrementado a lo largo del área de distribución de la vaquita en años recientes, especialmente por el resurgimiento de la pesquería de otra especie en peligro – la totoaba (*Totoaba macdonaldi*). Actualmente no es suficiente con eliminar solamente la pesca ilegal. Para ser efectivas, las regulaciones deben prohibir a los pescadores el uso, posesión o transporte de redes agalleras dentro de la zona de exclusión y esta medida deberá acompañase de vigilancia en mar y en tierra.

Los destinos de la totoaba y la vaquita han estado estrechamente vinculados. La zona de exclusión de chinchorros recomendada está enfocada en la zona de distribución de la vaquita. Sin embargo, es importante reconocer que la pesca ilegal de totoaba con chinchorro dentro de la zona de exclusión puede ser llevada a cabo por pescadores provenientes de los límites este o sur de la zona (incluyendo de Puerto Peñasco). El Gobierno de México podría considerar la necesidad de vigilancia en las comunidades aledañas a la zona de exclusión si la pesca ilegal de la totoaba continúa dentro de la zona, lo cual afecta negativamente a los esfuerzos para prevenir la extinción de la vaquita.

Al notar que esfuerzos pasados han fallado, **CIRVA recomienda firmemente que el Gobierno de México asigne recursos suficientes en vigilancia para asegurar que la pesca con redes agalleras sea eliminada dentro de la zona de exclusión.**

En resumen, la perspectiva general sobre el estado de la vaquita y la eficacia en las acciones de conservación ha cambiado drásticamente desde la última reunión del CIRVA hace solo dos años. En ese tiempo y por primera vez, CIRVA concluyó que había habido progreso, o que pronto lo habría, en la implementación de muchas de las recomendaciones hechas anteriormente por el Comité (Anexo 5). En contraste, la nueva información muestra una disminución catastrófica a menos de 100 individuos, lo cual ha cambiado el panorama sobre lo que es posible hacer con respecto a la adopción de redes alternativas – **ya no se puede esperar más tiempo para introducir de manera progresiva las nuevas tecnologías pesqueras hay que tomar acción inmediata para salvar a la vaquita.**

3. Esfuerzos de mitigación existentes y factores que afectan su éxito

3.1 BREVE RESEÑA DE RECOMENDACIONES PREVIAS DE LA COMISIÓN BALLENERA INTERNACIONAL (INTERNATIONAL WHALING COMMISSION – IWC) Y EL CIRVA

3.1.1 La IWC (Comisión y Comité Científico)

Por primera vez, el Comité Científico del IWC hizo recomendaciones sobre el estado crítico de la vaquita hace 24 años en 1990 (IWC, 1991). En retrospectiva, si todas estas recomendaciones se hubieran seguido en ese tiempo, sin duda la situación de la vaquita hubiera sido en gran parte resuelta. Estas recomendaciones son resumidas a continuación:

(1) vigilancia y cumplimiento total para la veda en la pesquería de totoaba y reconsiderar la emisión de permisos experimentales (de fomento) para la pesca de totoaba;

(2) tomar acción inmediata para detener el transporte ilegal de totoaba a través de la frontera con Estados Unidos;

(3) desarrollar e implementar un plan de manejo para la protección a largo plazo de la especie [vaquita] y su hábitat incluyendo:

- (a) evaluación sobre otras pesquerías que capturan o pudieran capturar vaquitas;
- (b) desarrollo e implementación de métodos alternativos de pesca u otras actividades económicas para los pescadores;
- (c) educar a los pescadores y al público sobre el estado precario de la vaquita;
- (d) monitorización del estatus y mejorar el conocimiento de la biología de la vaquita.

Desde entonces El Comité Científico ha emitido las recomendaciones, incrementando los niveles de urgencia (ver Fig. 1). La propia Comisión ha aprobado tres Resoluciones.

Hace seis años, en el 2008 (IWC, 2009) mientras acogía favorablemente la noticia de que Gobierno de México estaba tomando medidas para eliminar el chinchorro de línea que accidentalmente captura vaquitas, el Comité Científico estaba muy preocupado de que el periodo propuesto para la eliminación gradual 'dentro de tres años' podría no ser 'suficientemente rápido para prevenir su extinción'. El Comité reiteró su extrema preocupación acerca del estado de la conservación del cetáceo en mayor peligro de extinción del mundo. Expresó su gran frustración en que a pesar de más de una década de advertencias, la especie continúa su camino rápido hacia la extinción debido a la falta de medidas efectivas de conservación. Recomendó que, si se va a evitar la extinción, todas las redes agalleras deben ser eliminadas inmediatamente en la región del Alto Golfo de California. Además, señaló que en la muy desafortunada circunstancia de que esto no ocurriera de inmediato, sin duda tendrá que producirse en el plazo de tres años a partir de 2008.

3.1.2 CIRVA

En su primera reunión en 1997, el CIRVA identificó que la captura incidental por redes agalleras era la mayor amenaza para la sobrevivencia de la vaquita (Anexo 5 y Fig. 1). La segunda reunión del CIRVA en 1999 recomendó que las redes agalleras y las embarcaciones de altura camaroneras fueran prohibidas en una secuencia por etapas – que conduciera a una prohibición total en 2002. En su tercera reunión en el 2004, el CIRVA concluyó que la disminución de la población de la vaquita continuaba y que la tasa de captura incidental se habían incrementado desde la segunda reunión del CIRVA. Expresó su "**profunda preocupación** de que la especie permanecerá en un grave peligro de extinción en el futuro cercano, a menos de que medidas enérgicas de conservación sean implementadas inmediatamente por el Gobierno de México". En su cuarta reunión del 2012, el CIRVA reiteró que "Todas las redes agalleras y otras redes de enamlle necesitan ser retiradas del área total de distribución de la vaquita" y hacer un llamado para acelerar los esfuerzos para reconvertir a las embarcaciones artesanales de pesca de camarón, así como también a las de escama, a métodos de pesca que sean seguros para la vaquita lo antes posible. En la presente reunión, CIRVA notó que la evidencia presentada mostró que el esfuerzo pesquero no parece haber disminuido desde el 2006. El análisis de datos de la monitorización acústica indicó que la disminución catastrófica de la población de la vaquita ha continuado.

3.2 PROGRESO DE LA COMISIÓN ASESORA DE LA PRESIDENCIA DE LA REPÚBLICA PARA LA RECUPERACIÓN DE LA VAQUITA

3.2.1 Presentación

Luis Fueyo, Comisionado Nacional de Áreas Naturales Protegidas, reportó que al principio de la presente administración de la Presidencia de México, en Diciembre del 2012, el nuevo gobierno designó una nueva estrategia para recuperar especies en riesgo. El Presidente apoyó la formación de un grupo de alto nivel, la Comisión Asesora de la Presidencia de la República para la Recuperación de la Vaquita (bajo la presidencia de Fueyo), para asegurar la recuperación de la vaquita como prioridad del nuevo gobierno. Durante este mismo periodo, en Noviembre del 2012, los primeros indicadores serios sobre la pesca y comercialización ilegal de totoaba emergieron, haciendo que la integración de esfuerzos para la vigilancia por parte de diferentes agencias federales sea una de las prioridades de la nueva comisión.

Fueyo notó que el comercio de la totoaba es un problema serio y con un considerable respaldo financiero. No todas las agencias fueron capaces de lidiar con este problema complejo de pesca y comercio ilegal (ej. capacidad para identificar rápidamente productos pesqueros legales contra productos ilegales). Asimismo, reportó que el gobierno federal está proporcionando entrenamiento a diferentes agencias en tierra y en el mar. Se encuentra también estableciendo un grupo único de vigilancia entre las diferentes agencias, con PROFEPA, la Marina Nacional y CONAPESCA, entre otras, para el cumplimiento de la ley

Fueyo subrayó dos componentes diferentes en la situación de la totoaba. El primero es principalmente doméstico, muchas personas de las comunidades locales se encuentran involucradas en la pesquería ilegal. El Comisionado espera que conforme el costo de transición hacia redes de pesca libres de vaquita sea reducido, para los pescadores, existirán menos incentivos económicos para participar en la pesquería de totoaba. El segundo componente es internacional, he hizo notar que oficiales fronterizos de México y Estados Unidos están trabajando con el Servicio de Vida Silvestre y Pesca de EUA (US Fish and Wildlife Service) para identificar y cerrar las rutas de exportación para productos de totoaba.

Fueyo además reportó que la Comisión Presidencial ha hecho varias recomendaciones. En particular, las autoridades pesqueras han promulgado regulaciones en las que se requiere el cambio de redes agalleras a redes de arrastre ligeras para la pesquería de camarón. Se está llevando a cabo un gran esfuerzo para alinear los procesos de comunicación entre todas las agencias interesadas, con reuniones mensuales donde se identifican y atienden los problemas de mayor dificultad en la pesca ilegal.

En conclusión, Fueyo indicó que acepta la información científica proporcionada por el CIRVA y reconoce que la situación de la vaquita es grave. Confirma que es responsabilidad de la Comisión Presidencial el considerar todas las recomendaciones del CIRVA y hacer todo lo que esté en su poder para prevenir la extinción de la vaquita y apoyar su recuperación. Expresó confianza en que la Comisión Presidencial puede ayudar en este problema.

En respuesta a una pregunta, Fueyo reconoció que la reunión de cuatro horas propuesta por la Comisión Presidencial a finales de julio era inadecuada debido a la información científica reciente. El agregó que la reunión debería ser extendida hasta dos días para permitir más tiempo a la discusión y para el desarrollo de las recomendaciones para el Presidente. También mencionó que considerará el tener reuniones más frecuentes con la Comisión Presidencial para seguir los eventos más de cerca y para asegurar que todas las partes relevantes del gobierno se encuentren totalmente comprometidas con los esfuerzos relevantes de conservación de la vaquita.

3.2.2 Discusión

Durante la discusión, Young indicó que el Servicio Nacional de Pesquerías Marinas de los Estados Unidos (U.S. National Marine Fisheries Service) tiene disponibilidad para brindar asistencia al Gobierno de México para abordar el problema de la vaquita/totoaba. En particular, la vigilancia conjunta y la asistencia para entrenamiento son temas que pueden ser discutidos en el próximo encuentro sobre vigilancia entre México y los Estados Unidos.

En respuesta, Fueyo acordó en que el tema de la vaquita/totoaba podría ser abordado en reuniones entre las autoridades pesqueras Mexicanas y de los Estados Unidos y que debe prioritario en las agendas de las reuniones entre el Presidente Peña Nieto y el Presidente Obama. El identificó que la ayuda para llevar a cabo los cambios en los equipos de pesca y la cooperación en la vigilancia transfronteriza para detener el comercio ilegal son temas que deben ser consideradas. También destacó la importancia en dar continuidad a la asistencia internacional para el programa de monitoreo de vaquita.

Al cierre de la discusión general, Fueyo concluyó señalando que la mayoría de las personas trabajando en el Alto Golfo son pescadores, o que de alguna manera son dependientes de las pesquerías para sus modos de vida, y por lo tanto la dimensión social en los esfuerzos de conservación de la vaquita es de suma importancia. Del 2008 al 2011, muchas embarcaciones y permisos fueron retirados. El gobierno y las ONG deben esforzarse de manera urgente para asegurar que las personas sean capaces de ganarse la vida y de apoyar a sus familias a través de actividades legales.

3.2.3 Conclusiones del CIRVA

CIRVA agradeció a Fueyo por asistir a la reunión y notó que la Comisión Presidencial es clave para la sobrevivencia de la vaquita. Dio la **bienvenida** a la noticia de que la siguiente reunión de la Comisión podría ser extendida a dos días de duración. Aun reconociendo muchos de los retos logísticos, legales y socio económicos a enfrentar, CIRVA de nuevo **recalcó** que la información científica más reciente muestra que la situación es extremadamente grave y que acciones concertadas en todos los frentes son requeridas inmediatamente.

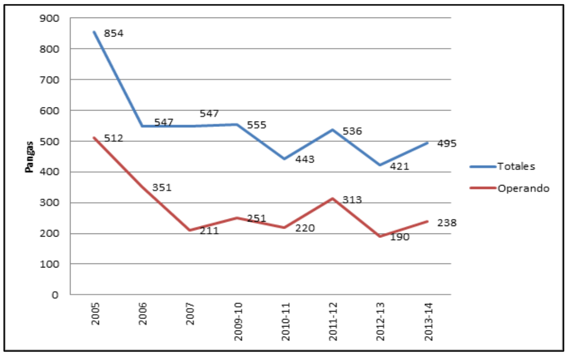
CIRVA está consciente de los problemas socio-económicos a los que las comunidades se enfrentan, pero señaló también que las recomendaciones para desarrollar métodos alternativos se han repetido durante más de 20 años (véase también 3.5). Además, un importante componente del problema con las redes agalleras tiene relación a las pesquerías ilegales, lo cual no debería ser permitido aún sin tomar en cuenta el problema de la vaquita.

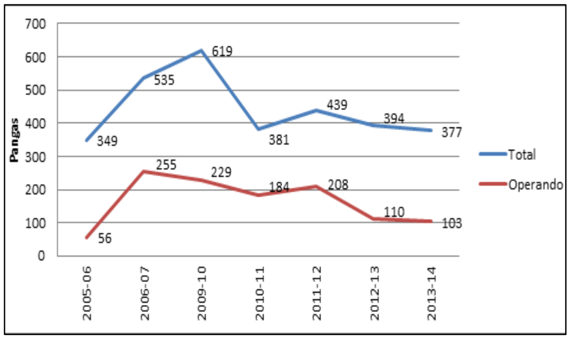
El CIRVA reconoce que su experiencia es principalmente científica, y que la experiencia sobre la temática social y económica será necesaria para abordar muchas de las preocupaciones de las comunidades. Sin embargo, el CIRVA se encuentra obligado, con base en lo que sus miembros conocen acerca de los animales y su entorno natural, a enfatizar que la situación es grave y que son necesarias acciones para eliminar las redes agalleras y asegurar el cumplimiento de las regulaciones. En la última reunión del CIRVA (en 2012), existían probablemente el doble de las vaquitas que existen actualmente. La tarea de los expertos de la Comisión Presidencial será la de convertir los consejos del CIRVA en acciones positivas antes de que sea demasiado tarde.

3.3 MONITORIZACIÓN DEL ESFUERZO PESQUERO

3.3.1 Presentación

Juan Manuel García (Sustainable Fisheries Partnership) presentó los resultados de los estudios aéreos sistemáticos sobre la distribución y número de pangas pescando en el Alto Golfo del 2005 al 2014 (Fig. 3). Estos estudios son apoyados por el Fondo Mexicano para la Conservación de la Naturaleza y han sido llevados a cabo mensualmente cada año durante el periodo de octubre a julio. Los transectos de las prospecciones están espaciadas por cinco millas náuticas, empezando tres millas al sur del Refugio de la Vaquita y extendiéndose hacia el norte con dirección al Delta. Los vuelos se hicieron durante periodos de buen clima y a una elevación de 1500 m.





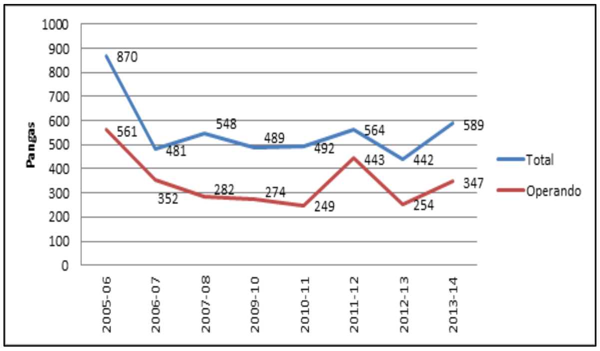


Figura 3 (arriba a la izquierda). Número total de pangas observadas de octubre a julio (azul) y número total de pangas observadas operando (pescando) durante este periodo (rojo).

Fig. 3 (abajo a la izquierda). Número total de pangas observadas durante la temporada de camarón de octubre a febrero (azul) y número total de pangas observadas operando (pescando) durante esa temporada (rojo)

Fig. 3 (arriba a la derecha). Número total de pangas observadas durante la temporada de pesca desde marzo a julio (azul) y número total de pangas observadas operando (pescando) durante esa temporada.

3.3.2 Conclusiones del CIRVA

Después de observar estos datos, el CIRVA concluyó que no existe una tendencia aparente en el número de pangas pescando en el Alto Golfo desde el 2006 (tanto en el número total como en el número observado pescando) y que no hubo un efecto aparente del programa de retiro del 2008 en el número de pangas activas o en la flota total. Además, estos estudios fueron realizados durante el día y por lo tanto podrían no detectar la pesca ilegal llevada a cabo durante la noche, tales como los lances de redes agalleras para totoaba.

El CIRVA **dio la bienvenida** a la presentación sobre los datos obtenidos de las prospecciones aéreas, pero le preocupó extremadamente que no mostrara evidencia de la disminución en el esfuerzo pesquero. Notó que era necesario un desglose geográfico y temporal más detallado para evaluar de una mejor manera el esfuerzo y para desarrollar escenarios para utilizarlos en el modelo de Gerrodette. El CIRVA **recomienda** que estos datos se hagan disponibles por parte del Fondo Mexicano para la Conservación de la Naturaleza. Rojas-Bracho **acordó** en escribirle la solicitud al FMCN a nombre del CIRVA.

No se proporcionó información cuantitativa, de INAPESCA, sobre el progreso en la reducción del esfuerzo pesquero como resultado de los trabajos de retiro o avances sobre la regulación que indica que todas las embarcaciones deberán cambiar el uso de redes agalleras hacia septiembre del 2016 (véase también 3.5.3.2).

3.4 ACTUALIZACIÓN SOBRE LA PESQUERÍA ILEGAL DE TOTOABA

3.4.1 Presentación

Martha Román proporcionó una breve actualización sobre la historia de la explotación y la situación actual con respecto a la pesca ilegal para totoaba en el Alto Golfo de California. Investigación sobre la biología de la totoaba llevada a cabo entre 2010 y 2013 indicó que había ocurrido una ligera recuperación después de un largo periodo de protección.

Sin embargo, debido a la creciente demanda de los mercados asiáticos por la vejiga natatoria (*localmente conocida como buche*) de la totoaba, ha habido un incremento en la presión por pesca ilegal hacia esta especie. La totoaba es capturada a través de redes agalleras con luz de malla grande, ancladas y dejadas sin atender por varios días. Las vejigas natatorias son usadas como alimento (en una sopa) en China donde se les atribuyen propiedades medicinales. En una operación de vigilancia, 529 vejigas natatorias fueron recuperadas; los pescadores podrían recibir hasta USD$8,500 por kilogramo de éste producto. Los niveles de esfuerzo pesquero ilegal han sido muy altos en comparación con el año pasado, y es posible que esta pesquería tenga un serio impacto sobre la población de totoaba.

3.4.2 Conclusión y recomendación del CIRVA

El CIRVA expresó su seria preocupación sobre esta información, **reiterando** que la pesca ilegal de totoaba con redes agalleras representa una amenaza importante para la sobrevivencia de la vaquita, como también para la sobrevivencia de la misma totoaba. Por lo tanto, el CIRVA recomienda que todas las herramientas de vigilancia disponibles, dentro y fuera de México, sean aplicadas para detener la pesca ilegal, especialmente para la captura de totoabas y la comercialización de sus productos.

3.5 METODOS ALTERNATIVOS DE PESCA

3.5.1 Progreso en métodos alternativos

Se presentó un extenso resumen sobre el trabajo emprendido para desarrollar e introducir métodos alternativos de pesca. Esto se ofrece como Anexo 4.

El desarrollo, adopción, y el uso de embarcaciones de arrastre artesanales para la pesca comercial del camarón se ha visto obstaculizado y retrasado por el abrumante bloqueo intencional y no intencional de las redes agalleras. La pesca con redes agalleras ha sido el método pesquero más fácil de usar y el menos costoso en términos de redes y de combustible. La eliminación de las redes agalleras en la zona de exclusión podría liberar a los pescadores con redes de arrastre artesanales, y otros equipos alternativos, de las restricciones por la presencia de redes de enmalle, creando así nuevas oportunidades para hacer realidad los beneficios económicos de los métodos de pesca alternativos. Las agencias gubernamentales deben continuar y aumentar su inversión en soluciones de artes de pesca alternativas, junto con la puesta en práctica de la de la zona de exclusión a las redes agalleras, recomendada anteriormente.

3.5.2 Conclusiones y recomendación del CIRVA

El CIRVA espera con interés las recomendaciones del comité técnico sobre tecnologías pesqueras de la Comisión Presidencial, pero reiteró que la nueva información científica demuestra que existe la necesidad de implementar la prohibición inmediata y total de redes agalleras, así como una vigilancia dentro de la zona de exclusión recomendada para redes agalleras.

El resultado de los esfuerzos para aplicar el mandato para cambiar las redes de enmalle de camarón a las *pequeñas* redes de arrastre ha sido decepcionante. Pescadores entrenados en el uso de esta red tuvieron problemas para obtener sus permisos. El CIRVA **recomienda** que la obtención de permisos debe racionalizarse y coordinarse para que cualquier pescador dispuesto al cambio pueda obtener permisos de manera eficiente. Estas fallas de parte del Gobierno de México envía un mensaje a otros pescadores que la legislación relativa a la conversión de artes de pesca no se hará cumplir, como ha sido el caso de otras leyes, como la destinada a la longitud legal de las redes de enmalle. Deben hacerse esfuerzos inmediatos para construir suficientes redes de arrastre artesanales y para capacitar a los pescadores, o de lo contrario se reforzará la percepción de que la nueva regulación no va a ser obligatoria y vigilada. Los pescadores deben estar convencidos en que el Gobierno de México es serio acerca de hacer cumplir las leyes. Este es un primer paso necesario como parte de los cambios drásticos en las prácticas pesqueras, los cuales deben llevarse a cabo si se pretende salvar a la vaquita.

Por último, el CIRVA hizo hincapié, en respuesta a las presentaciones sobre posibles nuevos diseños de pangas o de pequeños/ligeros arrastreros artesanales para camarón, que cuando se intorduce una nueva tecnología, la escala en la que se introduce tiene que tener en cuenta la sostenibilidad de las pesquerías y la condiciones y prácticas de las comunidades locales.

3.5.3 Plan preliminar de pruebas experimentales del INAPESCA

3.5.3.1 Presentación

Aguilar (INAPESCA) presentó un plan preliminar para un experimento de al menos de septiembre a diciembre 2014, para evaluar la rentabilidad y la eficiencia de la pesca con la red de arrastre pequeña/ligera. Afirmó que los estudios de los cinco años previos han sido afectados por la presencia de redes agalleras, ya que estos interfieren con las actividades de arrastre y se ha comprobado que es imposible obtener datos a lo largo de toda la temporada de pesca de camarón en estas condiciones. El experimento propuesto autorizaría únicamente la operación de redes de arrastre en la Reserva de la Biósfera durante la temporada de pesca de camarón. Aguilar mencionó que se espera que 50 pescadores operen con las redes arrastreras, respaldados por 50 observadores para colectar datos y 50 expertos para proporcionar capacitación. Los pescadores con permisos autorizados para el uso de redes agalleras tendrán una compensación para combustible, de tal manera que puedan operar fuera de la Reserva de la Biosfera. La posibilidad de incluir Sistemas de Información Geográfica en las embarcaciones podría ser investigada.

3.5.3.2 Discusión

Durante la discusión, se notó que existe suficiente evidencia de que las redes de arrastre son rentables; los estudios adicionales propuestos ayudarían a entender mejor la rentabilidad de estas redes, y por lo tanto a diseñar los esquemas de compensación. Se notó también que la presente regulación anticipa que el 30% de las pangas (i.e. 175) serán reconvertidas en Septiembre del 2014 (ver Tabla 2); por lo tanto, el número propuesto de 50 pescadores es muy pequeño, incluso en el contexto de la regulación que indica que la reconversión total deberá ser completada en septiembre del 2016. Tomando los números del experimento propuesto, la compensación para combustible podría ser proporcionada a pescadores de hasta 500 pangas, y todos o la mayoría de ellos podrían operar cerca del límite de cualquiera área de exclusión (de hecho, el límite propuesto atraviesa hábitat conocido de la vaquita).

Se notó que este plan sólo contempla a la pesca de camarón con chinchorro de línea. El CIRVA tiene la preocupación de que las redes agalleras para pesca de escama podrían estar permitidas y de que el apoyo financiero destinado al combustible pudiera incentivar a los pescadores a usar estos subsidios para pescar escama con red agallera dentro del área de la vaquita.

Finalmente, el CIRVA ha notado con anterioridad la importancia de asegurar que se proporcione suficiente equipo y capacitación para el uso de la red alternativa a la brevedad posible. Asimismo, considera que la compensación debe ponerse a disposición de los pescadores aún en caso de cualquier retraso entre la ejecución de la zona de exclusión de las redes de enmalle recomendada y la implementación de métodos de pesca alternativos.

Tabla 2

Calendario para la reconversión de la flota con redes agalleras de acuerdo con la norma Mexicana.

Zona	Total embarcaciones/permisos	Septiembre 2013-septiembre 2014	Septiembre 2014 – septiembre 2015	Septiembre 2015 – septiembre 2016
G de Santa Clara	426	128	128	170.4
San Felipe	158	47	47	63.2
Total	584	175	175	234
Total	100%	30%	30%	40%

3.5.2.3 Conclusiones y recomendaciones del CIRVA

El CIRVA agradeció a Aguilar su presentación. Mientras que algunos aspectos sobre el plan, los cuales son compatibles con las recomendaciones del CIRVA son bienvenidos (ej. incrementar la capacitación, el principio de exclusión de todas las redes agalleras en un área determinada, uso de GPS como parte de las prácticas de vigilancia), hace **hincapié** sobre los siguientes puntos:

(1) Las redes agalleras no son compatibles con la sobrevivencia de la vaquita. **Reitera** su recomendación descrita en el párrafo anterior sobre la eliminación total de todas las operaciones pesqueras con redes agalleras dentro la zona de exclusión que se muestra en la figura 2.

(2) La vigilancia es el problema más urgente que debe ser abordado para la implementación de una zona de exclusión. Una considerable pesca ilegal, que hace uso de redes agalleras, tiene lugar dentro del Alto Golfo, además de la pesquería ilegal de totoaba, que incluye la pesca sin permisos (o con permisos no vigentes), la utilización de redes agalleras con longitudes ilegales y la pesca dentro de áreas protegidas incluyendo el Refugio de la Vaquita.
Las medidas actuales de vigilancia son claramente inadecuadas, y la implementación efectiva de la recomendación del CIRVA sobre la eliminación de todos las redes agalleras requerirá un incremento considerable en los recursos y la monitorización para asegurar que la zona de exclusión esté funcionando como se pretende.
(3) Es **esencial** que equipos y capacitación suficientes estén disponibles a la brevedad posible.

3.6 PROGRESOS EN VIGILANCIA

3.6.1 Presentaciones

No hubo representantes de PROFEPA durante la reunión, por lo que Martín Sau presentó un breve resumen sobre los esfuerzos en la vigilancia de una presentación previa de PROFEPA en febrero del 2014. Esta presentación resumió los viajes de patrullaje en el 2013 (305), acciones contra los pescadores y confiscaciones de pescado o productos pesqueros ilegales, especialmente de totoaba. Las embarcaciones de vigilancia también encontraron y destruyeron 88 redes fantasma y confiscaron 16 redes ilegales a los pescadores. Trece embarcaciones fueron detenidas y confiscadas. PROFEPA reportó sobre sus equipos y personal en el Alto Golfo, el cual incluye nueve embarcaciones pequeñas, cuatro empleados permanentes tanto en Baja California como en Sonora, y cuatro empleados temporales en Baja California y ocho en Sonora.

Los ingresos de los pescadores por las vejigas natatorias confiscadas mediante las acciones de vigilancia podría estimarse en USD$2.25 millones, asumiendo que la vejiga promedio pesa ½ kg y que estas fueran vejigas de hembras, las cuales tienen mayor valor.

Durante la reunión, Sergio Pérez Valencia de CEDO proporcionó una actualización sobre la Manifestación de Impacto Ambiental (MIA) para la Pesca Artesanal en la Reserva de la Biósfera del Alto Golfo de California y el Delta del Río Colorado, la cual, como se explica en el CIRVA-4, fue designada para implementar medidas de mitigación y documentar el cumplimiento de las regulaciones pesqueras. La MIA está relacionada a 903 embarcaciones legales provenientes de las tres comunidades principales en el Alto Golfo, las cuales tienen como objetivo 27 especies y una variedad de aparejos de pesca. Este proyecto se adapta a las regulaciones ambientales y pesqueras actuales, proporciona mecanismos para distinguir fácilmente entre pescadores legales e ilegales, fortalece el co-manejo por parte de pescadores y el gobierno, facilita el manejo adaptativo y puede ser co-financiado por pescadores, gobierno y ONGs. De acuerdo con Pérez Valencia, progresos significativos han encaminado a los pescadores hacia prácticas pesqueras responsables basadas en la ciencia, participación de los pescadores en la toma de decisiones, capacitación y concientización. Sin embargo, los pescadores que desean cumplir con las regulaciones sienten que están siendo afectados cuando los pescadores ilegales operan sin límites o castigos. Existe la creciente preocupación de que la falta generalizada de vigilancia en la región llevará a un menor cumplimiento de las regulaciones pesqueras y pondrá en riesgo la renovación del proyecto de la MIA, el cual tiene una vigencia autorizada solamente hasta el 17 de diciembre del 2014.

3.6.2 Conclusiones y recomendación del CIRVA

Mientras que esta información es muy valorada, el CIRVA acuerda en que se requiere un reporte completo sobre vigilancia. **Recomienda** que una declaración clara de los recursos de PROFEPA y sus recursos destinados al Alto Golfo de California es necesaria, junto con información sobre todos los esfuerzos de cooperación con otras agencias. Esto debe ser proporcionado a la Comisión Presidencial junto con un plan detallado para la vigilancia de le las regulaciones. Una estimación informal indicó que se necesitarán incrementar los recursos presentes diez veces más solo para combatir la pesca ilegal de totoaba de manera efectiva.

Información anecdótica de los pescadores presentes en la reunión sugiere que ha habido un incremento en las actividades de vigilancia en tierra y en mar en San Felipe, incluyendo personal de la Marina, PROFEPA y CONAPESCA, particularmente durante la temporada de camarón.

Sin embargo, también notaron que una considerable actividad ilegal está teniendo lugar en la región, involucrando pangas provenientes de todo el Golfo de California y de puertos del Pacífico tales como Ensenada, pero que no se están tomando medidas serias de vigilancia a gran escala. Los pescadores presentes en el CIRVA-5 insistieron en que la vigilancia debe ser estratégica. Incluso un pequeño incremento en la vigilancia, si se lleva a cabo con inteligencia, podría resultar en un gran cambio en el comportamiento de los pescadores. Se debe enviar un fuerte mensaje de que la actividad ilegal será castigada.

3.7 CONSERVACIÓN EX-SITU

3.7.1 Discusión

El CIRVA consideró brevemente la posibilidad del enfoque de conservación *ex-situ*, el cual implica la extracción de individuos de la población salvaje, para desarrollar programas de reproducción en cautiverio o para salvaguardar a los pocos individuos restantes de la especie. Este enfoque requeriría: (1) capturar y transportar individuos salvajes; (2) mantenimiento de estos individuos en semi-cautiverio (hábitat natural) o en instalaciones especiales para cautiverio; y (3) liberación futura de individuos capturados en su medio natural o criados en cautiverio. Es posible que este enfoque también requiera un programa de reproducción y crianza en cautiverio si se espera que proporcione un verdadero beneficio para la conservación de la especie.

A la fecha no han habido intentos para capturar vaquitas o mantenerlas en cautiverio, pero las marsopas comunes han sido capturadas exitosamente en el noreste del Pacífico y al oeste de Groenlandia. Un número pequeño de marsopas comunes han sido mantenidas en cautiverio en diferentes partes del mundo pero pocos se han sido reproducidos en ese medio. Obviamente, el enfoque *ex situ* para las vaquitas requeriría desarrollar nuevos métodos para capturar y mantener a estos animales. No existe infraestructura que pueda ser utilizada para albergar vaquitas en el Alto Golfo, y la infraestructura más cercana y apropiada para la cautividad de éstos animales se encuentra en San Diego. El transporte a través de la frontera podría complicarse debido a los permisos y otros problemas legales. Este enfoque podría ser exitoso desde la perspectiva de la conservación únicamente si estos individuos, o su progenie pudieran ser eventualmente liberados en el medio natural. Existen varios retos para lograr tales retornos, liberaciones o reintroducciones. Entre más tiempo estén en cautiverio, mayor será la dificultad para regresar a estos animales a su medio natural. Además, no es viable capturar o mantener un número suficiente de animales para desarrollar un programa de reproducción en cautiverio para esta especie.

3.7.2 Conclusión del CIRVA

Por lo tanto, dados estos retos, el CIRVA **concluyó** que el enfoque *ex-situ* para la conservación de la vaquita no es viable. La Asociación de Zoológicos y Acuarios, la cual representa a 221 zoológicos y acuarios certificados en siete países, generó la misma conclusión la cual se describe en una carta enviada al Presidente Enrique Peña Nieto en Febrero del 2013.

4. Resumen de Recomendaciones

- CIRVA recomienda encarecidamente al Gobierno de México que promulgue normas de emergencia que establezcan una zona de exclusión de las redes de agalleras y de enmalle (Fig. 2) que cubre toda el área de distribución de la vaquita - no simplemente el refugio existente - a partir de septiembre de 2014.

- CIRVA recomienda que el Gobierno de México proporciona la suficiente vigilancia para garantizar que la pesca con redes de enmalle se elimina dentro de la zona de exclusión

- CIRVA recomienda que todas las herramientas de vigilancia y aplicación de la ley, dentro y fuera de México, se apliquen para detener la pesca ilegal, especialmente la captura de totoabas y el comercio de sus productos.

- CIRVA recomienda que el Gobierno de México proporcione una declaración clara de los recursos de la PROFEPA en el Alto Golfo de California, junto con información sobre cualquiera y todos los esfuerzos de vigilancia y aplicación de la ley de otras agencias.

- CIRVA recomienda que se hagan mayores esfuerzos para introducir alternativas a la pesca con redes de agalleras en las comunidades que se verán afectadas por la aplicación de la zona de exclusión.

- CIRVA recomienda que la expedición de permisos para la pesca con artes de pesca diferentes a las redes agalleras sea expedita.

- CIRVA recomienda que los datos de prospecciones aéreas sobre el esfuerzo pesquero y las escalas temporales y geográficas adecuadas se pongan a disposición del CIRVA por el Fondo Mexicano para la Conservación de la Naturaleza para mejorar los esfuerzos de modelación de la población (por ejemplo, por Tim Gerrodette; véase el anexo 3).

- CIRVA recomienda encarecidamente que el programa de monitoreo acústico continue indefinidamente, con el apoyo financiero adecuado, con el fin de determinar si los esfuerzos de mitigación están trabajando.

- CIRVA recomienda que se abandonen los intentos de instalar C-pods en las boyas del perímetro, pero en cambio se destinen los fondos para permitir que el personal del proyecto pueda recuperar y reparar o reemplazar los detectores acústicos dentro del refugio, según sea necesario, durante la temporada de muestreo con el fin de maximizar el tamaño de la muestra acústica y evitar lagunas de datos.

REPORTE DEL CIRVA-V

Anexo 1: Lista de Participantes

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Anexo 2: Agenda

Julio 8
9:00-9:30

1. Welcoming to participants (CONANP, Marine Mammal Commission y WWF).
2. Introduction of participants
3. Confirm chair and rapporteur(s)
4. Review and adopt the Agenda

9:30-10:30
Vaquita population trends and status

5. Report of the acoustic monitoring program (A. Jaramillo y G. Cárdenas)

11:00-1300

6. Report of the Vaquita acoustic Monitoring Steering Committee (A. Jaramillo y G. Cárdenas)
7. Report of the Expert Panel of Modelers on vaquita population trends (J. Barlow)
8. Current status of the vaquita population (B. Taylor)

14:30-17:00

9. A brief report on totoaba fisheries (M. Román)
10. Communicating the results of the vaquita population status to stakeholders
11. The monitoring program in the next years
12. Break to draft the report of this section of the meeting

Julio 9
8:30-900
13 .Review of the report Vaquita population trends and status
Mitigation approaches and timeframe
9:00 – 10:30
14. Introduction of participants for section
15. Short Review of previous recommendations by CIRVA and the IWC
16. Progress in the Presidential Commission

11:00 – 13:00
Technological development
Expert presentations (Chris Glass, Tim Werner)
17. Small trawl technology (Daniel Aguilar, Ramses Rodríguez, Antonio García)
18. Diesel vessels for small trawl (Antonio Murillo, Lázaro Espinoza)
19. Fishing lines as an alternative (Daniel Aguilar, Ramses Rodríguez, Carlos Samudio)
20. Fish traps as an alternative (Daniel Aguilar, Antonio García)

14:30-17:00
21. Alternative fisheries (Sergio A. Pérez y Lázaro Espinoza)
22. Concluding remarks and recommendations
23. Enforcement

Julio 10
09:30 – 16:30
24. Captive and *in situ* breeding
25. Drafting of the report
26. CIRVA recommendations and Report
27. Review of CIRVA-5
28. Adoption of the Repor

ANEXO 3: SEGUNDA REUNIÓN DEL COMITÉ DIRECTIVO DEL PROGRAMA DE MONITORIZACIÓN ACÚSTICA

Anexo 3: Segunda Reunión del Comité Directivo del Programa de Monitorización Acústica

Abril 24-25, 2014
Presidente: Armando Jaramillo
Asistentes: Lorenzo Rojas Bracho, Gustavo Cardenas Hinojosa, Edwina Nieto Garcia,
Francisco Valverde Esparza, Martín Sao,
Nick Tregenza, Tim Gerrodette, Barbara Taylor,
Jay Barlow, Tim Ragen, Annette Henry,
Eiren Jacobson

Resumen Ejecutivo

Resultados a mitad del proyecto de monitorización acústica indican una disminución crítica en la abundancia de vaquita desde 2011. Los datos brutos indican disminuciones de 7.5% y 14.9% en promedio de Minutos de Detección Positiva (un índice de densidad acústica de vaquitas) del 2011 al 2012 y del 2012 al 2013 respectivamente (Fig. 1). Los análisis indican que la disminución en abundancia de vaquita podría ser mayor. Las poblaciones pequeñas son vulnerables a riesgos múltiples y vinculados, tales como la depresión endogámica e incremento en la variabilidad en las tasas de crecimiento poblacional, que pueden acelerar el proceso de extinción. Conforme la población de vaquita disminuye, ésta puede alcanzar un punto de no retorno en el cual la recuperación ya no es posible. Desconocemos cual es este punto para la vaquita. Con base en estas preocupaciones, Jaramillo et al. (2007) escogió 50 adultos, un numero identificado por Franklin (1980) necesario para mantener la capacidad reproductiva. Los individuos adultos probablemente componen aproximadamente la mitad de la población actual de vaquita, por lo que el límite de abundancia total (para todas las edades) sería de alrededor de 100. Durante la 65va. Reunión del Comité Científico de la Comisión Ballenera Internacional (IWC) generaron un análisis a requerimiento del Gobierno de México. Utilizando un modelo Bayesiano se estimó una abundancia de 189 individuos (mediana de la distribución posterior) para la población de vaquita correspondiente a 2013.

El Comité Directivo del Programa de Monitorización Acústica encontró que la colocación y recuperación del equipo de monitoreo acústico (C-PODs) dentro del Refugio de Vaquita ha sido muy exitoso en los primeros tres años del proyecto a 6 años de duración. Se han recuperado más del 90% de los C-PODs puestos en el campo. Los C-PODs funcionaron bien y colectaron datos que serían suficientes para detectar un incremento anual de 4%, en caso de que dicho incremento ocurriera. Dos científicos procesaron los datos independientemente y compararon sus resultados con un programa diseñado para detectar vocalizaciones de marsopas. La comparación produjo resultados casi perfectamente similares. El Comité estuvo de acuerdo en que los datos fueron de alta calidad y que el desempeño de todo el equipo a cargo de este proyecto es excepcional.

ANEXO 3: SEGUNDA REUNIÓN DEL COMITÉ DIRECTIVO DEL PROGRAMA DE MONITORIZACIÓN ACÚSTICA

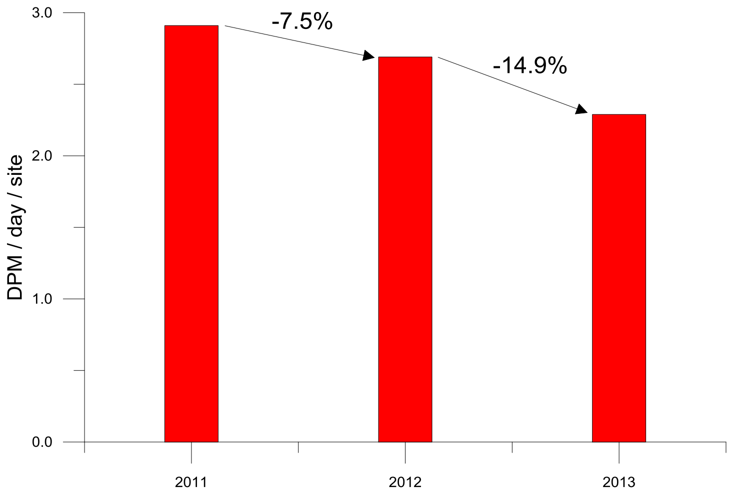

Figura 1. Promedio de minutos de detección por día por sitio de muestreo de los datos en bruto, mostrando la tasa de disminución entre años.

El Comité examinó el resumen estadístico de los datos crudos y los resultados detallados de los análisis para estimar la tasa de cambio en la abundancia de la vaquita. Todos los enfoques indicaron que la población de vaquita está disminuyendo y la tasa de disminución aparenta ser mayor que todas tasas las registradas con anterioridad para esta población. Dada esta abundancia críticamente baja, todos los escenarios plausibles indican que sin acciones efectivas de mitigación esta especie podría extinguirse en un futuro cercano.

El Comité discutió los factores que podrían generar confusión en la interpretación de los datos. Notablemente, las mayores tasas de detecciones fueron de los C-PODs localizados al sur, lo cual podría indicar que las vaquitas se movieron hacia el sur de la zona de monitoreo. Sin embargo, estudios anteriores han mostrado que la distribución de la vaquita ha sido muy consistente en largos periodos de tiempo (Fig. 2). Estos datos visuales indican un área de baja densidad desde hace mucho tiempo justo al lado de la frontera suroeste del Refugio. Actualmente, los datos del monitoreo para el área no están disponibles porque todos los C-PODs colocados aquí (en o justo afuera de la frontera suroeste del Refugio) se perdieron. Para confirmar que las vaquitas no están usando el área alrededor de la frontera suroeste del Refugio, el Comité también recomendó incrementar la vigilancia a lo largo de la esta frontera durante la temporada de muestreo y reemplazar los C-PODs frecuentemente durante la temporada para asegurar la pronta recuperación de los datos colectados.

El Comité estuvo de acuerdo en que las estimaciones de tasas de disminución anual de 2011 al 2013 son muy severas, y que el estado de la vaquita es tan serio que acciones inmediatas para salvar a esta especie son esenciales. Sin embargo, para confirmar estos resultados, el Comité está buscando los fondos necesarios y ha identificado un pequeño grupo de expertos adecuados para proporcionar la revisión.

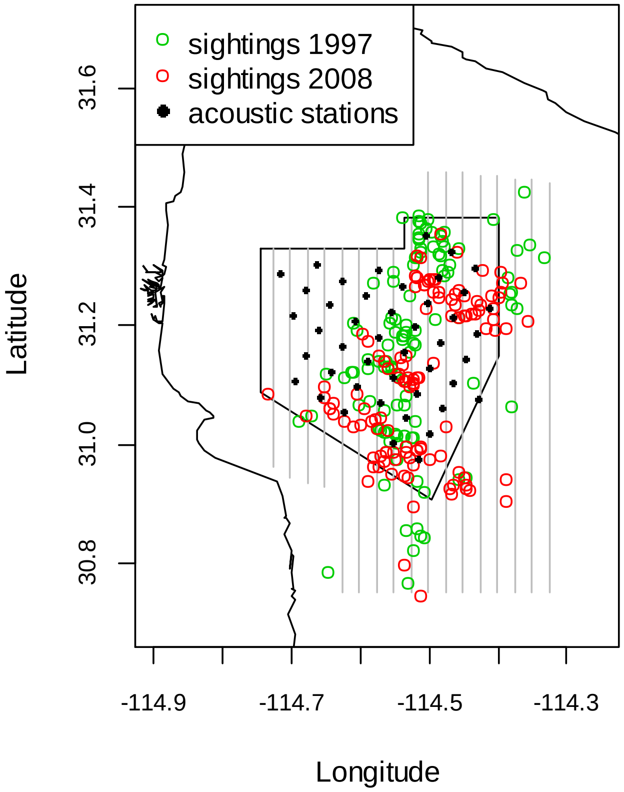

Figura 2. Detecciones visuales (círculos rojos y verdes) provenientes de los dos principales estudios para estimar abundancia, con los transectos mostrados con líneas grises. La ubicación de los detectores acústicos del programa de monitorización actual se muestra con puntos negros. El Refugio de Vaquita es el polígono en negro.

ANEXO-4: REUNIÓN DEL PANEL DE EXPERTOS EN DATOS ESPACIALES Y ACÚSTICOS

Anexo 4: Reporte sobre Tasa de Cambio de Vaquita Entre 2011 y 2013 Usando Datos Acústicos Pasivos

Panel de Expertos en Modelos Espaciales

Junio 24-26, 2014
Llevada a cabo en Southwest Fisheries Science Center, La Jolla, CA, USA

Participantes (*Analistas que constituyeron el Panel de Expertos):
Armando Jaramillo-Legorreta*
Lorenzo Rojas-Bracho
Jay VerHoef*
Jeff Moore*
Len Thomas*
Jay Barlow*
Justin Cooke*
Tim Gerrodette
Barbara Taylor

Resumen Ejecutivo

Después de revisar los resultados preliminares de las primeras tres temporadas (2011-2013) del programa de monitorización acústica, el Comité Directivo del Programa de Monitorización Acústica recomendó que un panel de expertos en análisis de datos espaciales y acústicos fuera convocado para estimar las tendencias en las detecciones acústicas de vaquita durante este periodo. El Panel de Expertos, el cual se reunió del 24 al 26 de junio del 2014, analizó estos datos y estimó un 33% de disminución en actividad acústica de vaquita en el área muestreada del 2011 al 2013. Esta tasa de disminución, 18.5% por año (Intervalo de Confianza Bayesiano del 95% ~ -0.46 - +0.19 por año), es mayor que cualquier tasa reportada previamente para vaquita. El panel encontró una alta probabilidad de que la actividad acústica ha disminuido (probabilidad =0.88) con una alta probabilidad de que la tasa de disminución de mayor a 10% por año (probabilidad =0.75). Otros factores, tales como los cambios en el esfuerzo pesquero deben ser considerados para generar mediciones apropiadas de incertidumbre en las tendencias de abundancia para la vaquita.

El Panel de Expertos consideró que el programa de monitoreo es adecuado, pero también notó que el análisis fue complicado debido a la pérdida de algunos C-PODs en 2011 y números bajos de grabaciones en muchos de los C-PODs en 2013. Se desarrollaron varios enfoques analíticos para tomar en cuenta el muestreo irregular; todos indicaron disminuciones importantes. El Panel notó que la variación anual en la proporción de vaquitas presentes dentro del área de monitoreo podría no ser precisa debido a que sólo se cuenta con los primeros tres de los seis periodos de muestreo planeados, pero que es muy posible que esta especie críticamente amenazada continúe disminuyendo a una tasa alta si las condiciones de pesca actuales se mantienen.

REPORT OF THE FIFTH MEETING OF THE 'COMITÉ INTERNACIONAL PARA LA RECUPERACIÓN DE LA VAQUITA' (CIRVA-5)

CIRVA members want to gratefully thank the Comisión Nacional de Áreas Naturales Protegidas / SEMARNAT, World Wildlife Fund México and US Marine Mammal Commission for providing the funds to organize the Fifth Meeting of the Comité Internacional para la Recuperación de la Vaquita, held at the Hotel Coral y Marina, Ensenada, B.C., México, July 8-10, 2014.

MARINE MAMMAL COMMISSION

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DE ÁREAS NATURALES
PROTEGIDAS

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Contents

ANNEXES

ANNEXES 7 – 9 ARE REPORTS OF MEETINGS RELATED TO THE ACOUSTIC MONITORING PROGRAM COMPLETED BEFORE CIRVA-V AND REVIEWED AT CIRVA-V. THEY ARE PAGE NUMBERED INDEPENDENTLY OF THE CIRVA-V REPORT. THEY ARE:

ANNEX 7: VAQUITA POPULATION TREND MONITORING SCHEME BASED ON PASSIVE ACOUSTICS DATA - PROGRESS REPORT FOR STEERING COMMITTEE – 19pp.

ANNEX 8: SECOND MEETING OF THE STEERING COMMITTEE OF THE VAQUITA ACOUSTIC MONITORING PROGRAM – 50pp.

ANNEX 9: EXPERT PANEL ON SPATIAL MODELS: REPORT ON VAQUITA RATE OF CHANGE BETWEEN 2011 AND 2013 USING PASSIVE ACOUSTIC DATA – 50pp.

Executive Summary of CIRVA-5

THE VAQUITA IS IN IMMINENT DANGER OF EXTINCTION

The fifth meeting of the Comité Internacional para la Recuperación de la Vaquita (CIRVA) was held at the Hotel Coral y Marina in Ensenada, BC from July 8 – 10, 2014.

At its last meeting in 2012, CIRVA estimated about 200 vaquitas remaining. Since then, about half of them are thought to have been killed in gillnets, leaving fewer than 100 individuals now. The vaquita is in imminent danger of extinction.

EMERGENCY REGULATIONS ARE REQUIRED

Despite all efforts made to date, the most recent acoustic data show the vaquita population to be declining at 18.5% per year (Fig. 1). The best estimate of current abundance is 97 vaquitas of which fewer than 25 are likely to be reproductively mature females. The vaquita will be extinct, possibly by 2018, if fishery by-catch is not eliminated immediately. Therefore, CIRVA **strongly recommends** that the Government of Mexico enact emergency regulations establishing a gillnet exclusion zone (Fig. 2) covering the full range of the vaquita - not simply the existing Refuge - starting in September 2014.

FULL ENFORCEMENT IS CRITICAL

Past at-sea enforcement efforts have failed and illegal fishing has increased in recent years throughout the range of the vaquita, especially the resurgent fishery for another endangered species - the totoaba. However, it is no longer sufficient to eliminate only illegal fishing as has been recommended many times in the past. With fewer than 100 vaquitas left, *all* gillnet fishing must be eliminated. To save this species from extinction, regulations must prohibit fishermen from deploying, possessing or transporting gillnets within the exclusion zone and must be accompanied by both at-sea and shore-based enforcement. CIRVA **recommends** that the Government of Mexico provide sufficient enforcement to ensure that gillnet fishing is eliminated within the exclusion zone. CIRVA further **recommends** that all available enforcement tools, both within and outside Mexico, be applied to stopping illegal fishing, especially the capture of totoabas and the trade in their products.

USE OF ALTERNATIVE GEAR

CIRVA **commends** the work undertaken to date on developing alternative fishing gear to gillnets but it is concerned at the slow progress of implementing the transition despite existing legislation. CIRVA **recommends** that the Government of Mexico expedite both the granting of permits for small-type shrimp trawls to trained fishermen and the investment in production of small-type trawl gear and the training of fishermen to fish with the new gear. It further **recommends** increased efforts to introduce alternatives to gillnet fishing in the communities that will be affected by enforcement of the exclusion zone.

CONTINUED MONITORING IS ESSENTIAL

Finally, CIRVA **commends** the excellent vaquita monitoring program and associated research. The monitoring program must be continued to determine whether new mitigation measures are working.

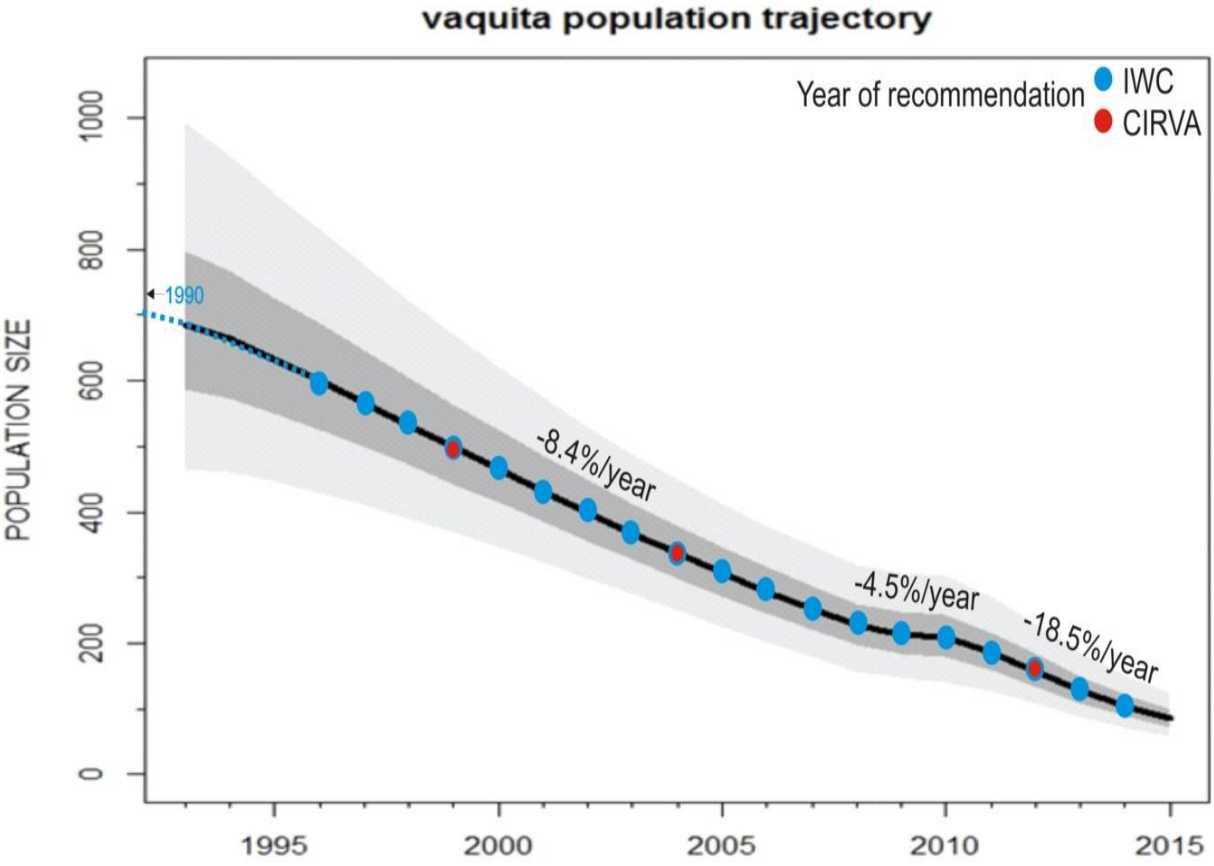
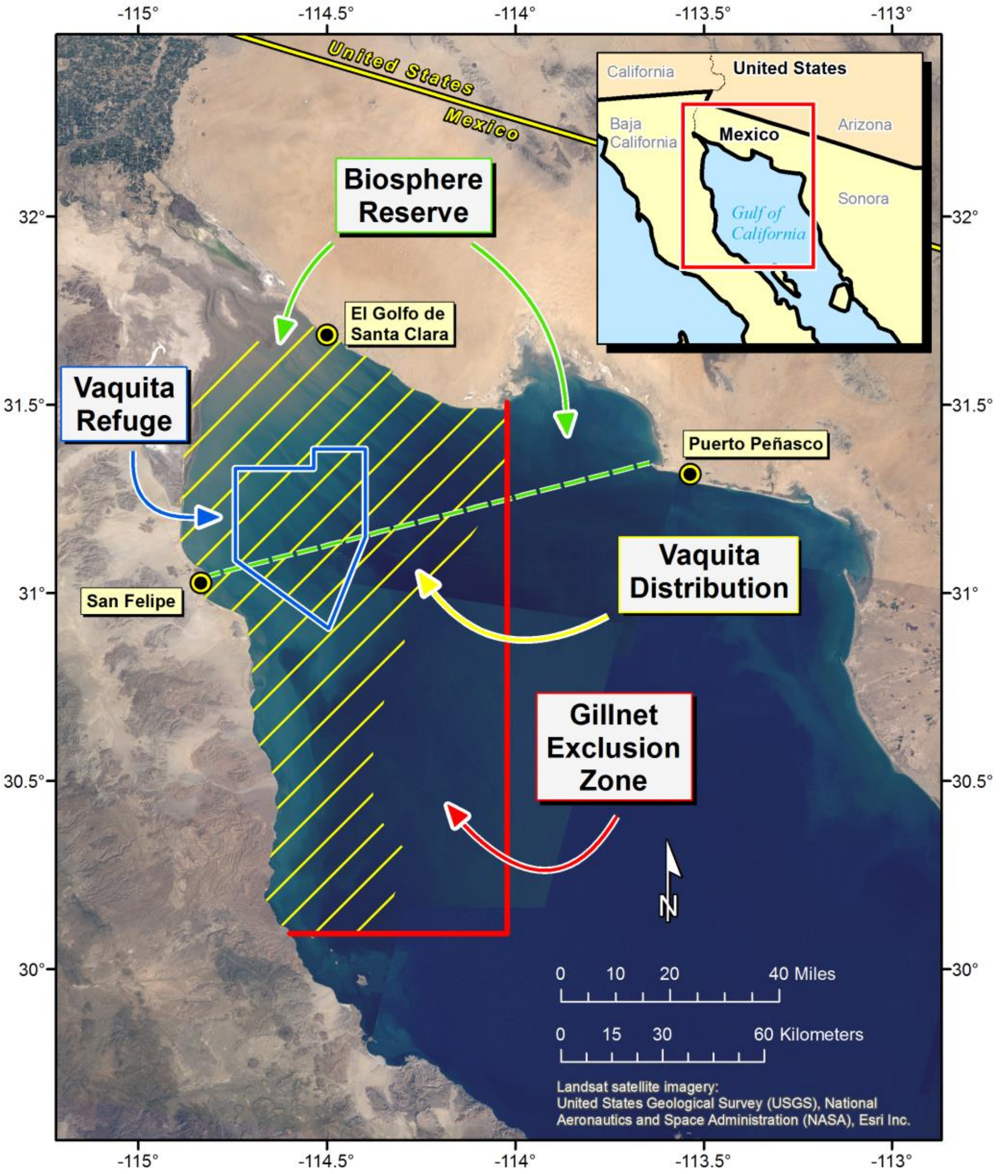


Figure 1. This figure depicts the population trajectory of the vaquita. Blue dots represent recommendations from the International Whaling Commission (IWC) and red dots represent recommendations from the International Committee for the Recovery of the Vaquita (CIRVA); both the IWC and CIRVA have recommended repeatedly that gillnets be eliminated from the range of the species (see Item 3.1). Rates of decline originate from Gerrodette and Rojas-Bracho (2011) prior to 2010 and from the Expert Panel results (Annex 8) using the passive acoustic data from 2011 onwards. The recent increase in the rate of decline can primarily be attributed to increased illegal gillnet fishing for totoaba.



Landsat satellite imagery:
United States Geological Survey (USGS), National Aeronautics and Space Administration (NASA), Esri Inc.

Figure 2. Gillnet exclusion zone proposed at the fifth meeting of CIRVA (north and west of red lines intersecting at 30º05’42”N, 114º01’19”W), which contains all the confirmed visual and acoustical detections of vaquitas since 1990 (yellow hatching). The exclusion zone encompasses vaquita critical habitat with muddy waters created by strong currents that comprise this critical habitat that can be seen in the satellite image. Further details on vaquita distribution are given in Annex 6. The polygon delimited by blue lines is the Vaquita Refuge established in 2005. Gillnet exclusion zone boundaries were also chosen for ease of use by fishermen and enforcement agents. A simple GPS reading or line of sight to well-known land markers can be used (‘Punta Borrascosa in the north and ‘Isla El Muerto in the west’).

REPORT OF CIRVA-V – EXECUTIVE SUMMARY

Mexico's Porpoise Nears Extinction: a simple statement on the situation now

The vaquita, a small porpoise found only in the upper Gulf of California in Mexico, is one of the world's most endangered mammals. In the past three years, half of the vaquita population has been killed in fishing nets, many of them set illegally to capture an endangered fish. Fewer than 100 vaquitas remain and the species will soon be extinct unless drastic steps are taken immediately.

The species was described in 1958 and has the smallest range of any whale, dolphin or porpoise. Vaquitas live in an area used intensively by fishermen from three small towns along the shores of the northern Gulf of California.

Vaquitas die after becoming entangled in gillnets. Gillnets are designed to entangle fish and shrimps but also capture other animals, including porpoises, dolphins and turtles. The Government of Mexico has been pursuing a conservation plan for the species that includes a refuge, where all commercial fishing (including with gillnets) is banned, and a program to encourage fishermen to switch to fishing gear that does not threaten vaquitas. Over the past five years, the Government invested more than $30 million (U.S.) in these efforts that slowed, but did not stop, the decline of the species. Scientists have warned for almost twenty years that anything short of eliminating gillnets would be insufficient to prevent the extinction of the vaquita.

A new, illegal fishery has emerged in the past few years that is an even greater menace to the vaquita. Many vaquitas have died in nets set for totoaba, a giant fish that can reach 2 m in length and 100 kg in weight. This endangered fish is prized for its swim bladder, which is exported to China where it is used as an ingredient in soup and believed to have medicinal value. Thousands of swim bladders are dried and smuggled out of Mexico, often through the United States. The remainder of the fish is left to rot on the beach. Fishermen receive up to $8,500 for each kilogram of totoaba swim bladder, equivalent to half a year's income from legal fishing activities.

At a meeting in July 2014, an international recovery team advising the Government of Mexico warned that time is rapidly running out. Unless drastic action is taken immediately, the vaquita will be lost. Mexican authorities must eliminate the gillnet fisheries that threaten the vaquita throughout the entire range of the species and enforce this gillnet ban. The Government must also stop illegal fishing for totoaba. The Governments of the United States and China must help Mexico eliminate the illegal trade in totoaba products. Unless these steps are taken immediately, the vaquita will follow the Yangtze River dolphin into oblivion and become the second species of whale, dolphin or porpoise driven to extinction in human history.

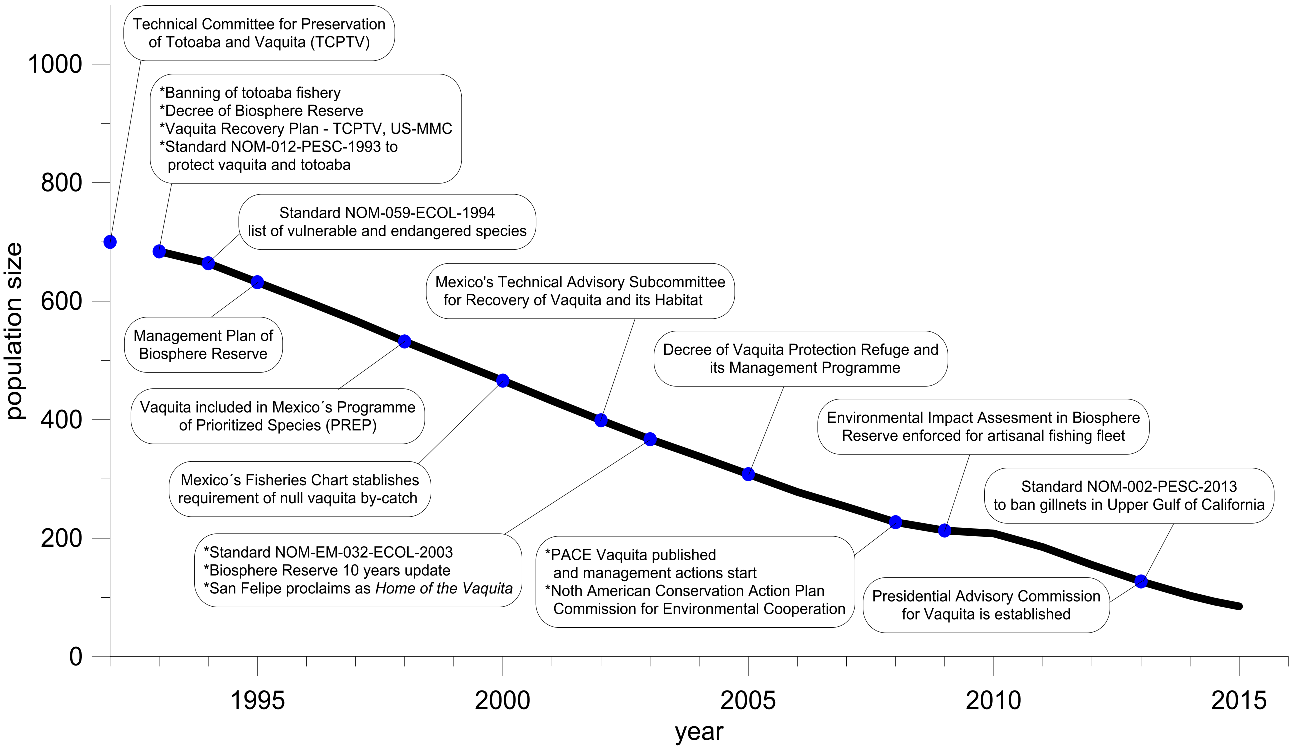


Figure showing the population decline of the vaquita alongside key management events.

1. Introduction

The fifth meeting of the Comité Internacional para la Recuperación de la Vaquita (CIRVA) was held at the Hotel Coral y Marina in Ensenada, BC from July 8 – 10, 2014. Lorenzo Rojas-Bracho welcomed participants and thanked CONANP, WWF and the U.S. Marine Mammal Commission for their support of the meeting.

The following CIRVA members attended: Lorenzo Rojas-Bracho (chair), Oscar Ramírez, Armando Jaramillo-Legorreta, Barbara Taylor, Jay Barlow, Arne Bjørge, Peter Thomas, Andrew Read, Robert Brownell, Greg Donovan and Randall Reeves.

Longtime CIRVA member Tim Gerrodette was unable to attend the meeting but contributed directly to the committee's work on abundance estimation (see Item 2.3 and Annex 3). A number of invited experts provided support by making presentations and contributing to the discussions. Rojas-Bracho chaired the meeting and Read, Thomas and Donovan served as rapporteurs with assistance from Reeves.

The full list of meeting participants is given in Annex 1. The agenda is given as Annex 2.

2. Population Trend and Status of the Vaquita

2.1 ACOUSTIC MONITORING

The information from the acoustic monitoring program and the analysis of the data obtained for the period 2011-2013 (Item 2.1.1) was reviewed extensively by first the Acoustic Monitoring Steering Committee (see Item 2.1.2) and then an Expert Panel (Item 2.1.2) before being considered by CIRVA.

2.1.1 Report of the Acoustic Monitoring Program

Jaramillo-Legorreta briefly reviewed the history of the passive acoustic monitoring program from its inception in 1997 to the present. The monitoring program currently employs autonomous echolocation click detectors (C-PODs) at 48 sites inside the Vaquita Refuge between June and September, when fishing effort in the region is relatively low, thereby minimizing the risk of losing equipment.

Jaramillo-Legorreta then presented the progress report of the acoustic monitoring program, which included results from the first three years of sampling (2011 – 2013) and an initial analysis of these data. This included an analysis of changes in the acoustic encounter rate, which was used as an index of population trend. The full progress report is attached as Annex 7.

Data are available from 127 C-POD deployments and 9,817 pod sampling days in the first three years of monitoring, which yielded 6,270 encounters. Vaquita echolocation was recorded most frequently in the southern portion of the Refuge.

This report had been submitted to the Acoustic Monitoring Steering Committee (see Item 2.1.2).

2.1.2 Report of the Acoustic Monitoring Steering Committee

Jaramillo-Legorreta then presented the report of the second meeting of the Steering Committee of the Vaquita Acoustic Monitoring Program, which convened in April 2014 to review the first three years of the Monitoring Program. The report of this meeting is appended as Annex 8. The Steering Committee concluded that the Monitoring Program had performed well and generated data of high quality and that the performance of the monitoring team had been exceptional.

The Steering Committee concluded that preliminary results of the Monitoring Program indicated that the vaquita population is declining at a rapid rate and that immediate action is necessary to save the species. Nonetheless, to confirm its findings, the Steering Committee convened an Expert Panel (see Item 2.1.3) to agree on: (1) the best measure of acoustic detections and (2) the best estimate of rate of change from 2011-2013 using the acoustic data alone.

2.1.3 Report of the Expert Panel

The Expert Panel met in June 2014 to review the findings of the Monitoring Program. The panel consisted of six modeling experts, including two from the Vaquita Acoustic Monitoring Steering Committee (Jaramillo-Legorreta and Barlow) and four globally recognized experts in spatial statistics and population trend analysis. The report of the Expert Panel is appended as Annex 9.

The Expert Panel considered the monitoring design to be sound, but noted that analyses were complicated by the loss of some C-PODs in 2011 and low numbers of recording days for numerous C-PODs in 2013. It developed several analytical approaches to account for the uneven sampling; all indicated substantial declines. The Panel agreed that year-to-year variation in the proportion of vaquitas present within the monitoring area could not be accounted for with only three of the intended six sampling periods completed, but that it is very likely that this critically endangered species has continued to decline at a high rate.

The Expert Panel generated an independent estimate of the rate of decline from 2011 to 2013 using the acoustic encounter data from the Monitoring Program. The best estimate of this rate of decline was 18.5% per year, a value much greater than any rate of decline previously reported for vaquitas. The Panel found a very high probability (88%) that the rate of acoustic encounters had declined during the monitoring period, with a strong likelihood (75%) that the rate of decline has been greater than 10% per year.

2.1.4 CIRVA conclusions

CIRVA **agreed** with the conclusions of the Expert Panel and **commended** the efforts of the acoustic monitoring team. It noted that this program had yielded one of the most complete pictures of the distribution and relative abundance of any endangered marine mammal. It **agreed** that the analyses presented by the Expert Panel (above) represented the present best estimate of the rate of decline of the vaquita between 2011 and 2013 i.e. 18.5%.

2.2 FUTURE OF THE ACOUSTIC MONITORING PROGRAM

In addition to the usual sampling grid, five more C-PODs were deployed in the southern portion of the monitoring area in 2014. This will be the fourth year of the Monitoring Program within the Vaquita Refuge. CIRVA **agreed** with the conclusions of the Expert Panel that the Monitoring Program inside the Refuge is working as intended. CIRVA **strongly recommends** that this program continue indefinitely, with strong financial support, in order to determine whether mitigation efforts are indeed working.

Jaramillo-Legorreta reported on the problems that had been experienced in trying to deploy acoustic detectors on the buoys delimiting the Vaquita Refuge. So far, four different mooring techniques have been tested; however in all cases most of the detectors were lost or stolen. CIRVA concluded that the information obtained from acoustic detectors deployed in buoys would be of marginal value. CIRVA therefore **recommends** that attempts to deploy C-PODS on the perimeter buoys be abandoned, and that instead funds be allocated to enabling project personnel to retrieve and repair or replace acoustic detectors inside the refuge as needed during the sampling season in order to maximize acoustic sample size and minimize data gaps.

2.3 CURRENT STATUS OF THE VAQUITA

Taylor presented the results of an analysis conducted by Tim Gerrodette that estimated the vaquita population size in mid-2014. Details of Gerrodette's analysis are presented in Annex 3. This projection employed the recent rate of decline in acoustic encounters estimated by the Expert Panel (18.5% per year). The approach assumes that acoustic encounters are directly proportional to population size within the monitored area and that abundance inside the refuge is proportional to total population size. CIRVA agreed that these were reasonable assumptions.

This approach shows that using the most recent information (see Item 2.1.3), the best estimate of current vaquita abundance is 97 animals. This means that likely fewer than 25 reproductively mature females remain.

CIRVA **endorsed** Gerrodette's approach and agreed that his analysis represented the best assessment of the present status of the vaquita.

2.4 CIRVA CONCLUSIONS AND RECOMMENDATIONS

Despite all efforts made to date, analysis of the acoustic indicates that the vaquita population is declining at 18.5% per year, the species has most likely been reduced to fewer than 100 individuals (see CIRVA-4) and the vaquita may be extinct by as early as 2018 if fishery by-catch is not eliminated immediately (Fig. 1). CIRVA views this new evidence with grave concern and strongly recommends that the Government of Mexico enact emergency regulations establishing a gillnet exclusion zone (Fig. 2) starting in September 2014.

Justification for the area of the exclusion zone is given in Annex 6. CIRVA believes that this species can recover but only if bycatch is eliminated immediately. It noted that other populations of marine mammals have recovered from similarly very low numbers, including northern elephant seals that were protected by Mexico in 1922.

Past at-sea enforcement efforts have failed, and illegal fishing has increased throughout the range of the vaquita in recent years, especially the resurgent fishery for another endangered species - the totoaba (*Totoaba macdonaldi)*. It is now not sufficient to eliminate only illegal fishing. With fewer than 100 vaquitas left, *all* gillnet fishing must be eliminated. To be effective, regulations must prohibit fishermen from deploying, possessing or transporting gillnets within the exclusion zone and must be accompanied by both at-sea and shore-based enforcement.

The fates of the totoaba and the vaquita have been closely linked. The recommended gillnet exclusion zone is focused on the vaquita's distribution. However, it is important to recognize that illegal gillnet fishing for totoaba within the exclusion zone could be carried out by fishermen from areas to the south or east of the zone boundaries (including from Puerto Peñasco). The Government of Mexico will need to enforce gillnet elimination regulations in communities outside the exclusion zone if it is found that illegal totoaba fishing is continuing within the zone, thereby undermining efforts to prevent extinction of the vaquita.

Noting that past enforcement efforts have failed, **CIRVA strongly recommends that the Government of Mexico allocates sufficient enforcement resources to ensure that gillnet fishing is eliminated within the exclusion zone.**

In summary, the general outlook on the status of the vaquita and the efficacy of conservation actions have changed dramatically from the last CIRVA meeting only 2 years ago. At that time and for the first time, CIRVA concluded that progress was being made, or soon would be made, toward implementing many of the committee's past recommendations (Annex 5). In contrast, the new information showing a catastrophic decrease to fewer than 100 individuals has changed the landscape of what is now possible in terms of adopting alternative gear **- there is no longer time to wait to phase-in new fishing technologies before immediate action is taken to save the vaquita**.

3. Existing mitigation efforts and factors affecting their success

3.1 SHORT REVIEW OF PREVIOUS RECOMMENDATIONS BY THE IWC AND CIRVA

3.1.1 The IWC (Commission and Scientific Committee)

The International Whaling Commission (IWC) Scientific Committee first made major recommendations on the critical status of the vaquita 24 years ago (IWC, 1991). With the benefit of hindsight, if those recommendations had been followed, there is little doubt that the vaquita situation would now have been largely resolved. Those recommendations can be summarised as:

(1) fully enforce the closure of the totoaba fishery and reconsider the issuance of permits for experimental totoaba fishing;

(2) take immediate action to stop the illegal shipment of totoaba across the US border;

(3) develop and implement a management plan for the long-term protection of the species [vaquita] and its habitat including:

(a) an evaluation of other fisheries that take or may take vaquitas;
(b) development and implementation of alternative fishing methods or other economic activities for fishermen;
(c) education of fishermen and the public of the precarious state of the vaquita;
(d) monitoring of status and improved knowledge of vaquita biology.

Recommendations have been issued regularly by the Scientific Committee since then, with increasing levels of urgency (see Fig. 1). The Commission itself has passed three Resolutions.

Six years ago (IWC, 2009), the Scientific Committee, whilst welcoming information that the Mexican Government was taking measures to eliminate the fishing gear that accidentally kills vaquitas, was greatly concerned that the proposed phase-out period 'within three years' might not be 'rapid enough to prevent extinction." The Committee reiterated its extreme concern about the conservation status of the most endangered cetacean species in the world. It expressed great frustration that despite more than a decade of warnings, the species had continued on a rapid path towards extinction due to a lack of effective conservation measures. It strongly recommended that, if extinction was to be avoided, all gillnets must be removed from the upper Gulf of California immediately. It stated further that in the extremely unfortunate circumstance that this did not occur immediately, it would certainly have to occur within the three-year period starting in 2008.

3.1.2 CIRVA

At its first meeting in 1997, CIRVA identified gillnet bycatch as the greatest threat to the survival of the vaquita (Annex 5 and Fig. 1). The second CIRVA meeting in 1999 recommended that gillnets and large industrial shrimp trawlers be banned in a staged sequence – leading to a total ban by 2002. At its third meeting in 2004, CIRVA concluded that the decline of the vaquita population was continuing and bycatch rates had increased since the second CIRVA meeting. It expressed '**grave concern** that the species will remain in serious danger of extinction in the near future, unless strong conservation measures are implemented immediately by the Government of Mexico.' At its fourth meeting in 2012, CIRVA reiterated that "All gillnets and other entangling nets need to be removed from the entire range of the vaquita" and called for expedited efforts to convert shrimp fishing vessels, as well as finfish vessels, to known vaquita-safe methods as soon as possible. At the present meeting, CIRVA noted that the evidence presented showed that fishing effort does not appear to have declined since 2006. The analysis of the acoustic monitoring data indicated that the catastrophic decline of the vaquita population has continued.

3.2 PROGRESS OF THE ADVISORY COMMISSION OF THE PRESIDENCY OF MEXICO FOR THE RECOVERY OF THE VAQUITA

3.2.1 Presentation

Luis Fueyo, National Commissioner for Natural Protected Areas, reported that at the start of the Mexican Presidential administration in December 2012 the new government designed a new strategy to recover species at risk. The President supported the formation of a high-level group, the Advisory Commission of the Presidency of Mexico for the Recovery of the Vaquita (under Fueyo's chairmanship), to ensure the recovery of the species, thereby indicating that he viewed actions to ensure the recovery of the vaquita as a priority of the new Government. During this same period, in November 2012, the first indications of the serious illegal take and trade of totoaba emerged, making integration of the efforts of different federal agencies in the law enforcement process a top priority of the new Commission.

Fueyo noted that the totoaba trade is a serious problem with considerable financial backing. Not all agencies are as yet able to deal with this complex illegal fishery and trade problem (e.g. able to quickly identify legal versus illegal fish products). He reported that the federal government is providing training to different agencies on land and at sea. It is also establishing a unique interagency law enforcement group with PROFEPA, the Navy and CONAPESCA, among others.

Fueyo stressed two different components of the totoaba situation. The first is primarily domestic in that many people in local communities are engaged in the illegal fishery. He hopes that as the cost to fishermen of making the transition to vaquita-safe gear is reduced, they would have less economic incentive to participate in the totoaba fishery. The second component is international and he noted that Mexican and US customs officials are working with the US Fish and Wildlife Service to identify and close the export routes for totoaba products.

Fueyo further reported that the Presidential Commission has made a number of recommendations. In particular, the fisheries authorities have enacted regulations requiring a switch from gillnets to light trawls in the shrimp fishery. A strong effort is being made to align communication processes among all concerned agencies, with monthly meetings being used to identify and address the more difficult problems of illegal fishing.

In conclusion, Fueyo indicated that he accepts the scientific information provided by CIRVA and recognizes that the situation for the vaquita is grave. He confirmed that it is the responsibility of the Presidential Commission to consider all the CIRVA recommendations and do all in its power to prevent the vaquita's extinction and support its recovery. He expressed confidence that the Presidential Commission can help with this issue.

In response to a question, Fueyo recognized that the proposed 4-hr meeting for the Presidential Commission at the end of July was inadequate given the new scientific information. He agreed that the meeting should be expanded to up to two days to allow more time for discussion and development of advice to the President. He also said he would consider having the Presidential Commission meet more frequently to follow events more closely and ensure that all relevant parts of the government are fully engaged with the vaquita conservation effort.

3.2.2 Discussion

In discussion, Young indicated that the U.S. National Marine Fisheries Service is willing to provide assistance to the Government of Mexico in addressing the vaquita/totoaba problem. In particular, joint enforcement and assistance with enforcement training are topics that can be discussed at the upcoming enforcement summit between Mexico and the United States.

In response, Fueyo agreed that the vaquita/totoaba topic should be addressed in meetings between US and Mexican fisheries authorities and that it should be high on the agenda of meetings between President Peña Nieto and President Obama. He identified help with gear changes, and cross-border co-operation on enforcement to stop illegal trade as areas that should be considered. He also noted the continued importance of international assistance with the monitoring program.

At the close of the overall discussion, Fueyo concluded by pointing out that most people working in the Upper Gulf are fishermen, or otherwise dependent on fisheries for their livelihood, and therefore that the social dimension of the vaquita conservation effort is of utmost importance. From 2008 to 2011 a lot of the boats were retired and permits withdrawn. Government and NGOs must strive as a matter of urgency to ensure that people are able to earn their livelihoods and support their families from legal activities.

3.2.3 CIRVA conclusions

CIRVA thanked Fueyo for attending the meeting and noted that the Presidential Commission is the key to the survival of the vaquita. It **welcomed** the news that the next meeting of the Commission would be expanded to up to two days. While recognizing the many logistical, legal and socio-economic challenges, CIRVA again **stressed** that the new scientific information shows the situation to be extremely grave and that concerted action on all fronts is required immediately.

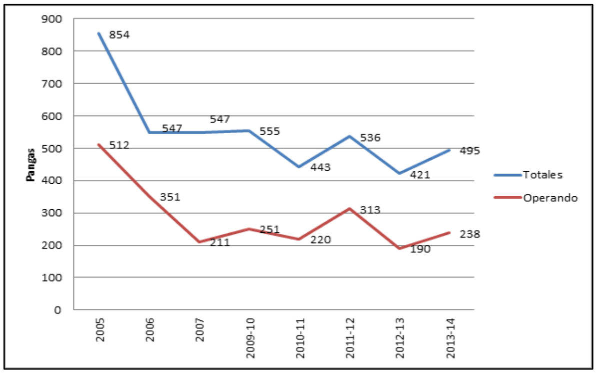
CIRVA is well aware of the socio-economic problems faced by the communities but noted that recommendations to develop alternative methods have been made repeatedly for over 20 years (and see Item 3.5). In addition, an important component of the gillnet problem relates to illegal fisheries, which should not be allowed even without the vaquita issue.

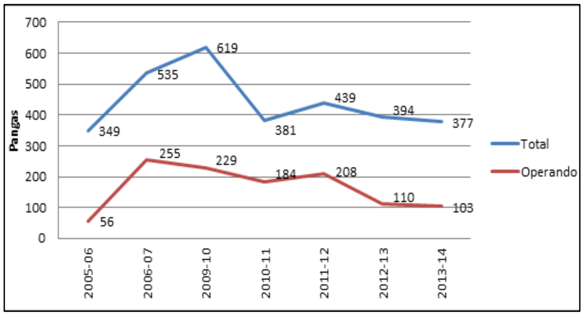
CIRVA recognized that its expertise is primarily scientific and that social and economic expertise will be needed to address many of the concerns of the communities. CIRVA is nonetheless compelled, based on what its members know about the animals and their natural environment, to emphasize that the situation is dire and action on removing gillnets and ensuring compliance is needed immediately. The last time CIRVA met (in 2012), there were probably twice as many vaquitas as there are now. The task facing the experts within the Presidential Commission is to translate CIRVA's advice into positive action before it is too late.

3.3 MONITORING FISHING EFFORT

3.3.1 Presentation

Juan Manuel García (Sustainable Fisheries Partnership) presented the results of systematic aerial surveys of the distribution and number of pangas fishing in the Upper Gulf from 2005 to 2014 (Fig. 3). These surveys are supported by the Mexican Fund for Conservation of Nature and have been conducted monthly each year during the period from October to July. The survey lines are spaced five nautical miles apart, beginning three miles south of the Vaquita Refuge and extending north to the Delta. Surveys are flown during periods of good weather at an altitude of 1500m.





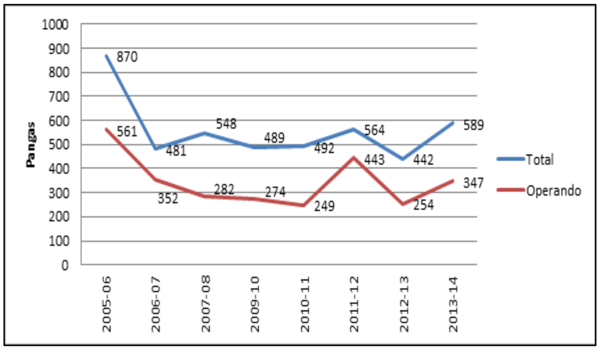


Figure 3 (top left). Total number of pangas observed from October to July (blue) and total number of pangas observed operating (fishing) during that period (red).

Fig. 3 (bottom left). Total number of pangas observed during the shrimp season from October to February (blue) and total number of pangas observed operating (fishing) during that season (red).

Fig. 3 (top right). Total number of pangas observed during the finfish season from March to July (blue) and total number of pangas observed operating (fishing) during that season.

3.3.2 CIRVA conclusions

After viewing these data, CIRVA concluded that no trend was apparent in the number of pangas fishing in the Upper Gulf since 2006 (either in the total number or the number observed fishing) nor was there any apparent effect of the buyout in 2008 on the number of pangas in the active or total fleet. Furthermore, these surveys were conducted in daytime and thus would not detect illegal night-time fishing, such as with gill nets set for totoaba.

CIRVA **welcomed** the presentation on the aerial survey data but was extremely concerned that it showed no evidence of a decrease in fishing effort. It noted that a more detailed geographical and temporal breakdown was required to better evaluate effort and develop scenarios for use with the

Gerrodette model. CIRVA **recommends** that these data are made available by the Mexican Fund for Conservation of Nature. Rojas-Bracho **agreed** to write on behalf of CIRVA with this request.

No quantitative information was provided to the meeting by INAPESCA on progress with the reduction in fishing effort as a result of the buyout work or in light of the legal requirement that all boats are to be converted from gillnetting by September 2016 (see Item 3.5.3.2).

3.4 UPDATE ON ILLEGAL TOTOABA FISHERY

3.4.1 Presentation

Martha Román provided a brief update on the history of exploitation and current situation regarding the illegal fishery for totoaba in the Upper Gulf of California. Research into the biology of totoaba conducted between 2010 and 2013 indicated that some recovery had occurred following a long period of protection.

However, due to increased demand in Chinese markets for the swim bladder (*vejiga natatoria*, or locally *buche*) of the totoaba, there has been a large increase in illegal fishing pressure on this species. Totoaba are captured in anchored, large mesh gill nets set at night and left unattended for several days. The swim bladders are used as food (in soup) in China where they are believed to have medicinal value. In one law enforcement operation, 529 swim bladders were recovered; fishermen may receive up to US$8500/kg for these bladders. Levels of illegal fishing effort have been very high over the past year and this fishing likely has had a serious impact on the totoaba population.

3.4.2 CIRVA conclusion and recommendation

CIRVA expressed its serious concern at this information, **reiterating** that the illegal gillnet fishery for totoaba poses a major threat to the survival of the vaquita, as well as to the totoaba itself. CIRVA therefore **recommends** that all available enforcement tools, both within and outside Mexico, be applied to stopping illegal fishing, especially the capture of totoabas and the trade in their products.

3.5 ALTERNATIVE METHODS OF FISHING

3.5.1 Progress on alternative methods

An extensive summary was presented of the work being undertaken to develop and introduce alternative fishing methods. This is given as Annex 4.

The development, adoption, and deployment of small trawls in the commercial fishery for shrimp has been hampered and delayed by the overwhelming intentional and unintentional blocking effect of gillnets. Gillnetting has been the easiest fishing method to use as well as the least costly in terms of nets and fuel. The elimination of gillnets in the recommended exclusion zone would release the fishermen using artisanal shrimp trawls and other alternative gear from the constraints of gillnet presence, thus creating new opportunities to realize the full economic benefits of the alternative fishing methods. Government agencies must continue and increase their investment in alternative gear solutions along with the recommended implementation of the gillnet exclusion zone.

3.5.2 CIRVA conclusions and recommendation

CIRVA looked forward to the recommendations from the technical committee on fishing gear of the Presidential Commission but reiterated that the new scientific information shows that there needs to be a complete and immediate ban on gillnets with full enforcement within the recommended gillnet exclusion zone.

The outcome of efforts to implement the mandated switch from shrimp gillnets to *small* trawls has been disappointing. Fishermen trained in the use of this gear had problems obtaining permits. CIRVA **recommends** that obtaining permits be streamlined so that any willing fisherman can obtain permits efficiently. To date, fishermen have not been provided with the gillnet-free space needed to operate the small trawls successfully. These failures on the part of the Government of Mexico send a message to other fishermen that the law pertaining to gear conversion will not be enforced, as has been the case with other laws such as that dealing with the legal length of gillnets. Immediate efforts should be made to build sufficient small trawls and train fishermen; failure to enable the conversion to small trawls will reinforce the perception that the new regulation will not be enforced. Fishermen must be convinced that the Government of Mexico is serious about enforcing the laws. This is a necessary first step in bringing about the dramatic changes in fisheries practices that must occur if the vaquita is to be saved.

Finally, CIRVA **emphasized**, in response to presentations on possible new designs of pangas or small/light shrimp trawlers, that if and when new technology is introduced, the scale at which it is introduced has to take into account the sustainability of the fisheries and the conditions and practices of local communities.

3.5.3 INAPESCA Experimental Testing Preliminary Plan

3.5.3.1 Presentation

Aguilar (INAPESCA) presented a preliminary plan for an experiment from at least September to December 2014 to assess the profitability and efficiency of fishing with the small/light trawl. He stated that the previous five years of studies had suffered because the presence of gillnetters had interfered with trawling and because it had proven impossible to obtain data throughout the full shrimp season. The proposed experiment would allow only trawl nets to be deployed and to operate in the Biosphere Reserve during the shrimp season. Aguilar said he expects 50 fishermen to operate trawls, backed up by 50 observers to collect data and 50 experts to provide training. Fishermen with gillnet permits would be given fuel compensation so they could operate outside the Biosphere Reserve. The possibility of including GIS on the vessels would be investigated.

3.5.3.2 Discussion

In discussion, it was noted that sufficient evidence exists that trawls are profitable; the proposed further studies would clarify how profitable and thus help inform compensation schemes. It was also noted that the present law anticipates that 30% of pangas (i.e. 175) will have been converted from gillnetting by September 2014 (see Table 2); thus the proposed number of 50 fishermen is far too small, even in the context of the existing law that states that total conversion from gillnets in the shrimp fishery must be completed by September 2016. Taking the proposed experiment at face value, compensation for fuel might be provided to fishermen on up to some 500 pangas and all or most of these could operate close to the edge of any closed-area boundary (and in fact the proposed boundary crosses some known vaquita habitat).

It was noted that this plan only contemplates shrimp gillnets. CIRVA is concerned that finfish gillnets would be allowed and that funding of fuel could result in fishermen using this subsidy to fish within the vaquita area using gillnets.

Finally, CIRVA has previously noted the importance of ensuring that sufficient equipment and training in the use of alternative gear are provided as rapidly as possible. It also believes that compensation should be made available to fishermen in the event of any delay between enforcement of the recommended gillnet exclusion zone and implementation of alternative fishing methods.

Table 2

Timetable for conversion of the gillnet fleet according to Mexican law.

Zone	Total vessels/permits	September 2013-September 2014	September 2014 – September 2015	September 2015 - September 2016
G de Santa Claro	426	128	128	170.4
San Felipe	158	47	47	63.2
Total	584	175	175	234
Total	100%	30%	30%	40%

3.5.3.3 CIRVA conclusions and recommendations

CIRVA thanked Aguilar for his presentation. While welcoming some aspects of the plan that are compatible with CIRVA recommendations (e.g. increased training, the principle of excluding all gillnets in an area, use of GPS as part of enforcement), it **stresses** the following points.

(1) Gillnets are not compatible with survival of the vaquita. It **reiterates** its recommendation above for a complete removal of all gillnet operations within the exclusion zone shown in Fig. 2.

(2) Enforcement is the most urgent problem that must be addressed in the implementation of an exclusion zone. Considerable illegal fishing with gillnets takes place within the Upper Gulf in addition to the illegal totoaba fishery, including fishing without permits (or with expired permits), using illegal lengths of gillnets and fishing within protected areas including the Vaquita Refuge. Present enforcement measures are clearly inadequate and effective implementation of the CIRVA recommendation to remove all gillnets will require a considerable increase in resources and monitoring to ensure that the exclusion zone is functioning as intended.

(3) It is **essential** that sufficient training and equipment are made available as soon as possible.

3.6 PROGRESS ON ENFORCEMENT

3.6.1 Presentations

No representative of PROFEPA was present at the meeting so Martin Sau presented a short summary of enforcement efforts from a previous PROFEPA presentation in February 2014. This presentation summarized enforcement trips in 2013 (305), actions against fishermen and seizures of illegal fish or fish products, especially totoaba. Enforcement vessels also encountered and destroyed 88 ghost nets and confiscated 16 illegal nets from fishermen. Thirteen boats were seized and confiscated. PROFEPA reported on its equipment and personnel in the upper Gulf, including nine small boats and four permanent staff in both Baja California and Sonora with four seasonal employees in Baja and eight in Sonora.

The revenue that went to fishermen for the bladders confiscated in that enforcement action would be US$2.25 million, assuming the average bladder weighs ½ kg and that these were the more valuable female bladders.

During the meeting, an update was provided by Sergio Perez Valencia of CEDO on the Environmental Impact Assessment (EIA) for Small-scale Fishing in the Upper Gulf of California and Colorado River Delta Biosphere Reserve which, as explained at the last CIRVA meeting (2012), was designed to implement mitigation measures and document compliance with fishery regulations. The EIA pertains to 903 legal boats from the three main communities in the upper Gulf that target 27 species with a variety of fishing gear. It is tailored to current fishery and environmental regulations, provides mechanisms for easily distinguishing between legal and illegal fishermen, strengthens co-management by fishermen and government, facilitates adaptive management and can be co-financed by fishermen, government and NGOs. According to Perez Valencia, significant progress has been made in redirecting fishermen towards responsible fishing practices based on science, enabling fishermen to participate in decision making and in terms of training and awareness. However, fishermen who wish to comply with regulations feel they are being undercut when illegal fishermen operate without constraints or punishment. There is growing concern that the general lack of fisheries law enforcement in the region will lead to less compliance and jeopardize renewal of the EIA project, which is authorized only until December 17, 2014.

3.6.2 CIRVA conclusions and recommendation

While appreciative of this information, CIRVA agreed that a full report on enforcement is required. It **recommends** that a clear statement of the resources of PROFEPA and its resources in the Upper Gulf of California is needed, along with information on all co-operative efforts of other agencies. This should be provided to the Presidential Commission along with a comprehensive plan to enforce regulations. An informal estimate was put forward indicating that present resources would need to be increased tenfold to effectively combat the illegal totoaba fishery alone.

Anecdotal information from the fishermen present suggested that there had been increased enforcement activity on land and at sea in San Felipe, including navy personnel, PROFEPA and CONAPESCA, particularly during the shrimp season.

However, it was also noted that considerable illegal activity continues to take place in the region, involving pangas from all over the Gulf of California as well as from Pacific ports such as Ensenada, but that no serious or large-scale enforcement measures are taken. The fishermen present at the meeting insisted that enforcement should be strategic. Even a small increase in enforcement, if done intelligently, could result in a big change in how fishermen behave. A strong message must be sent that illegal activity will be punished.

3.7 EX-SITU CONSERVATION

3.7.1 Discussion

CIRVA considered briefly the possibility of an *ex-situ* conservation approach, which would involve removing individuals from the wild population, either to develop a captive breeding program or to safeguard the last few individuals of the species. Such an approach would require: (1) capture and transport of wild individuals; (2) maintenance of these individuals in a semi-captive (natural habitat) or captive facility; and (3) release of wild-caught or captive-bred individuals into the wild at some future date. It is likely that the approach would also require a successful captive breeding program if it were to provide a real conservation benefit.

There have been no past attempts to capture vaquitas or maintain them in a captive environment, but harbor porpoises have been captured successfully in the north-eastern Pacific and off West Greenland. Small numbers of harbor porpoises are maintained in captivity in several parts of the world and a few animals have been bred in captivity. Obviously any *ex-situ* approach with vaquitas would require development of new methods to capture and hold these animals. There are no facilities that could be used to house vaquitas in the Upper Gulf and the closest captive facility that could support such animals is in San Diego. Transportation across the border could be complicated for permit and other legal issues. This approach would be successful from a conservation perspective only if such individuals, or their progeny, could eventually be released into the wild. There are several challenges to such returns, releases or reintroductions. The longer animals are maintained in captivity, the more difficult it is to release them back into the wild. In addition, it is not feasible to capture or hold a sufficient number of animals to develop a captive breeding program for this species.

3.7.2 CIRVA conclusion

Given these challenges, therefore, CIRVA **concluded** that an *ex-situ* approach to conservation of the vaquita was not feasible. The Association of Zoos and Aquariums, which represents 221 accredited zoos and aquariums in seven countries, reached the same conclusion in a letter sent to President Enrique Peña Nieto in February 2013.

4. Summary of Recommendations

- CIRVA **strongly recommends** that the Government of Mexico enact emergency regulations establishing a gillnet exclusion zone (Fig. 2) covering the full range of the vaquita - not simply the existing Refuge - starting in September 2014.
- CIRVA **recommends** that the Government of Mexico provide sufficient enforcement to ensure that gillnet fishing is eliminated within the exclusion zone
- CIRVA **recommends** that all available enforcement tools, both within and outside Mexico, be applied to stopping illegal fishing, especially the capture of totoabas and the trade in their products.
- CIRVA **recommends** that the Government of Mexico provide a clear statement of the resources of PROFEPA in the Upper Gulf of California, along with information on any and all co-operative enforcement efforts of other agencies.
- CIRVA **recommends** that increased efforts be made to introduce alternatives to gillnet fishing in the communities that will be affected by enforcement of the exclusion zone.
- CIRVA **recommends** that issuance of permits for legal non-gillnet fishing be expedited.
- CIRVA **recommends** that aerial survey data on fishing effort and appropriate temporal and geographical scales are made available to CIRVA by the Mexican Fund for Conservation of Nature to enhance population modelling efforts (e.g. by Tim Gerrodette; see Annex 3).
- CIRVA **strongly recommends** that the acoustic monitoring program continue indefinitely, with adequate financial support, in order to determine whether mitigation efforts are working.
- CIRVA **recommends** that attempts to deploy C-PODS on the perimeter buoys be abandoned, but instead funds should be allocated to allow project personnel to retrieve and repair or replace acoustic detectors inside the refuge as needed during the sampling season in order to maximize acoustic sample size and avoid data gaps.

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Annex 2: Agenda

Julio 8
9:00-9:30
1. Welcoming to participants (CONANP, Marine Mammal Commission y WWF).
2. Introduction of participants
3. Confirm chair and rapporteur(s)
4. Review and adopt the Agenda

9:30-10:30
Vaquita population trends and status
5. Report of the acoustic monitoring program (A. Jaramillo y G. Cárdenas)

11:00-1300
6. Report of the Vaquita acoustic Monitoring Steering Committee (A. Jaramillo y G. Cárdenas)
7. Report of the Expert Panel of Modelers on vaquita population trends (J. Barlow)
8. Current status of the vaquita population (B. Taylor)

14:30-17:00
9. A brief report on totoaba fisheries (M. Román)
10. Communicating the results of the vaquita population status to stakeholders
11. The monitoring program in the next years
12. Break to draft the report of this section of the meeting

Julio 9
8:30-900
13 .Review of the report Vaquita population trends and status
Mitigation approaches and timeframe
9:00 – 10:30
14. Introduction of participants for section
15. Short Review of previous recommendations by CIRVA and the IWC
16. Progress in the Presidential Commission

11:00 – 13:00
Technological development
Expert presentations (Chris Glass, Tim Werner)
17. Small trawl technology (Daniel Aguilar, Ramses Rodríguez, Antonio García)
18. Diesel vessels for small trawl (Antonio Murillo, Lázaro Espinoza)
19. Fishing lines as an alternative (Daniel Aguilar, Ramses Rodríguez, Carlos Samudio)
20. Fish traps as an alternative (Daniel Aguilar, Antonio García)

14:30-17:00
21. Alternative fisheries (Sergio A. Pérez y Lázaro Espinoza)
22. Concluding remarks and recommendations
23. Enforcement

Julio 10
09:30 – 16:30
24. Captive and *in situ* breeding
25. Drafting of the report
26. CIRVA recommendations and Report
27. Review of CIRVA-5
28. Adoption of the Report

Annex 3: Estimation of current vaquita population size

Tim Gerrodette, Southwest Fisheries Science Center, NOAA Fisheries, La Jolla, CA

The PACE Vaquita conservation action plan was adopted in the spring of 2008. The conservation plan proposed three options for closing areas to gillnet fishing in order to protect vaquitas. Gerrodette and Rojas-Bracho (2011) estimated the probability of success of the three options, based on a population model using data on visual sightings, acoustic detections, amount of fishing effort and vaquita bycatch. The conservation plan also established an acoustic monitoring program (Rojas-Bracho et al. 2010). After a period of development and testing from 2008-2010, the program collected extensive acoustic data in 2011, 2012 and 2013. The acoustic data have been analyzed by an expert panel to estimate the rate of change in acoustic activity at the locations of the recording devices (Jaramillo Legorreta et al 2014). Here we bring together the results of these two previous analyses to estimate the current size of the vaquita population.

To estimate current (mid-2014) vaquita abundance, we begin with the estimate of abundance at the end of 2009 based on the model of Gerrodette and Rojas-Bracho (2011). We use 2009 because the model included the effects of reduced fishing in 2008 and 2009 under PACE Vaquita, but did not include data after that. As used in the model, the estimate for a calendar year meant the population size at the end of the year. Thus, the number of vaquitas on 31 Dec 2009 was estimated to be 209 with a central 95% credibility interval from 130 to 321. In this paper, we change the year convention slightly to a more intuitive interpretation by considering this the estimate of 1 Jan 2010 and plotting this estimate on the 2010 tick mark. For the remainder of this document, abundance estimates are interpreted as the population size on Jan 1 of the year given. The present task is to estimate the current (mid-2014) population size. In the terms of the model, this is year 2013.5, which can be confusing, hence the change in presentation. Numerical results are unaffected.

The acoustic monitoring program uses an array of about 45 C-PODs with the Vaquita Refuge. Each C-POD records vaquita clicks for about 3 months during the summer. Analysis of the acoustic data is complicated by the fact that, for a variety of reasons, data are not recovered from every C-POD for the full monitoring period for every year. The expert panel convened to analyze the acoustic data considered several statistical models to estimate the annual rate of change indicated by the C-POD data. For projecting the vaquita population, we use the results of the panel's analyses, which was an average of the two best models (Jaramillo Legorreta et al 2014).

To estimate current vaquita abundance from these acoustic data requires two important assumptions:

(1) Acoustic encounter rates are proportional to vaquita abundance. Porpoise acoustic monitoring programs around the world rely on this assumption. Porpoise click activity, as well as detecting clicks with a device such as a C-POD, depends on many factors. We assume that the temporal and spatial extent of the C-POD array, together with the statistical analyses, are sufficient to account for these factors. Gerrodette et al (2011) estimated a rate of decline (7.6%) between 1997 and 2008 from visual data that was the same as the rate estimated by Jaramillo-Legorreta (2008) from acoustic data for the same period, which provides some support for this assumption.

(2) Vaquita abundance at C-POD locations during the summer acoustic monitoring period is proportional to total vaquita abundance. C-PODs are located several kilometers apart, and the detection range of a C-POD is limited to a few tens of meters. Vaquitas are not detected when they move in the areas between C-PODs, and vaquitas also move outside the area covered by the array of C-PODs. However, the C-PODs are placed in a regular grid with the Vaquita Refuge, which is the central part of the vaquita range containing about 50% of the population. While Gerrodette et al (2011) found a 57% decline in total abundance and a 59% decline in abundance in the core region (similar to the Refuge Area), this cannot be considered strong support because the two estimates are strongly correlated. The variation in the proportion of vaquitas that are near C-POD locations at any moment is not known. The projection presented here assumes that the roughly 2-month core acoustic sampling period is long enough to average over this variability.

The projection of the vaquita population starts with the posterior distribution of abundance at the beginning of 2010, as described above, and proceeds to mid-2014. The period covered by the acoustic monitoring data is from mid-2011 to mid-2013 (Jaramillo Legorreta et al 2014). We assume that the same trend in the population, a change of -18.5%/year, has continued from mid-2013 to mid-2014. To project the population between the beginning of 2010 and mid-2011, we use the mean of this trend and the trend (about -4%/year) that was occurring between 2008 and 2010 in the first 2 years of the PACE Vaquita conservation plan, as estimated by the model of Gerrodette and Rojas-Bracho (2011). Thus, the rate of population change during the 1.5-year period between the start of 2010 and mid-2011 was about -11%/year.

The mean rate of annual change during 2011-2013 indicated by the acoustic data, -18.5%/year, seems reasonable given reports of increased fishing for totoaba and lax enforcement of the ban on gillnet fishing in the Vaquita Refuge. However, the posterior distribution of the rate of annual change is quite broad, with 2.5% and 97.5% quantiles of 0.54 and 1.19, respectively. These rates imply a nearly 50% annual decline for the lower limit and a 19% per year growth for the upper. These rates are not credible. They are based on the acoustic data only, and do not take account of other data, such as the amount of fishing effort and the reproductive capacity of porpoises. Prior to the CIRVA meeting, there was not time to conduct an analysis which would constrain the posterior distribution of the acoustic data by taking these other data into account. Therefore, the projection of the vaquita population from the beginning of 2010 to mid-2014 presented in this document was based on the mean values of the posterior distributions described above. The width of the posterior distribution of the mid-2014 abundance estimate depends only on the uncertainty in the 2010 estimate from Gerrodette and Rojas-Bracho (2011) projected forward. The variance of the mid-2014 population estimate is therefore underestimated. We focus instead on the mean trend of the population and the mean 2014 estimate, which are substantially unaffected.

The posterior distribution of mid-2014 vaquita abundance ranges from about 50 to 150 animals (Fig. 1). This distribution has a mean of 97 and a median of 94 (Table 1). Thus, the current best estimate of vaquita abundance is that the population consists of fewer than 100 animals. Between 1993 and 2014, the population has declined from about 700 to 100 animals (Fig. 2). The probability that the population is below 100, which CIRVA has previously identified as a critical number below which the population may not recover, will become certain in the next few years (Fig. 3).

ANNEX 3: ESTIMATE OF CURRENT VAQUITA POPULATION

The last sentence of Gerrodette *et al.* (2011) stated: "The array of acoustic recorders will provide feedback to managers about whether the conservation plan is working and the vaquita population is recovering, or whether further steps need to be taken to save this porpoise from extinction." We now have data from the first 3 years of acoustic monitoring. The results indicate clearly that the vaquita population is declining even more rapidly than previously estimated, that the current population is very small and vulnerable, and that strong and immediate management actions are necessary to prevent extinction of the species.

Literature cited

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Rojas-Bracho, L., A. Jaramillo-Legorreta, G. Cárdenas, E. Nieto, P. Ladron de Guevara, B. L. Taylor, J. Barlow, T. Gerrodette, A. Henry, N. J. C. Tregenza, R. Swift, and T. Akamatsu. 2010. Assessing trends in abundance for vaquita using acoustic monitoring: within refuge plan and outside refuge research needs., NOAA Technical Memorandum 459, 39 p.

Table 1

Summary statistics of the posterior distribution of the number of vaquitas alive in July 2014, rounded to the nearest whole number.

mean	mode	min	max	2.5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	97.5%
97	89	33	211	60	71	78	85	89	94	101	105	114	125	144

ANNEX 3: ESTIMATE OF CURRENT VAQUITA POPULATION

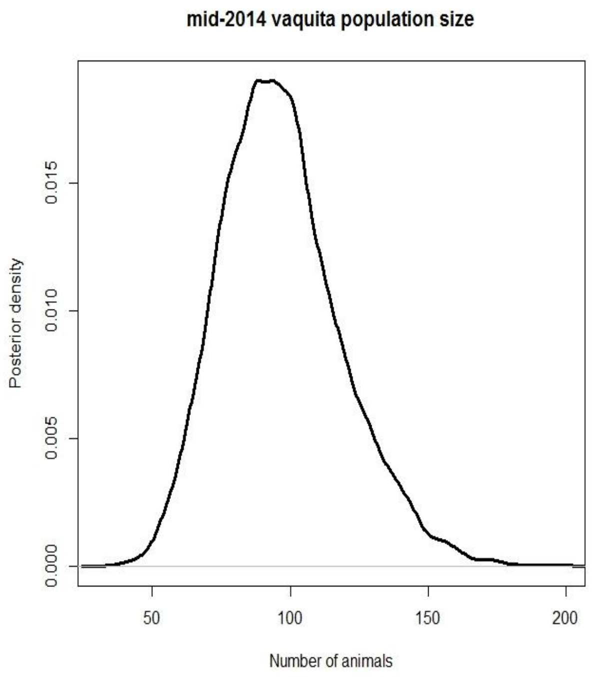

Figure 1. Posterior distribution of the number of vaquitas alive in July 2014.

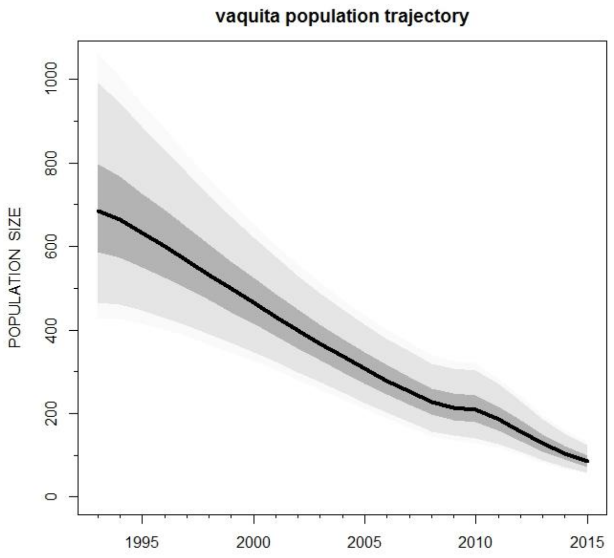

Figure 2. The estimated trajectory of the vaquita population from 1993 through 2014. The black line is the median, and the three shades of gray are 50%, 90%, and 95% of posterior probability density.

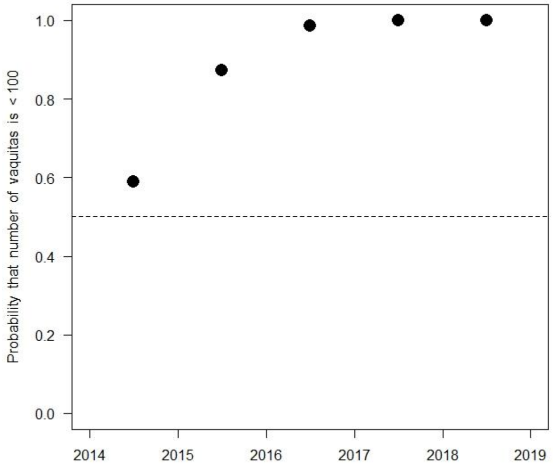

Figure 3. Probability that vaquita population size will be <100 animals at the midpoints of the next 4 years. The first point represents the current (mid-2014) population size.

Annex 4: Alternative technologies and fisheries

INTRODUCTION

As explained in detail in the main CIRVA report, all gillnets need to be removed immediately from the entire range of the vaquita if species extinction is to be prevented. Combinations of partial area and seasonal closures with different levels of enforcement are not only inadequate for protecting vaquitas, but such measures also cause fishermen to lose revenue. The development and implementation of new technologies could bring benefits to both vaquitas and fishermen.

Over the last decade, several efforts have been made to find the best technological solutions. In 2004 WWF, INAPESCA and experts from Memorial University of Newfoundland started testing traps for catching shrimp. In 2006 INAPESCA started testing small nets powered by wind developed in Sinaloa, called suripera nets. In 2008, after four years of research, INAPESCA concluded that conditions in the upper Gulf are not suitable for shrimp traps and suriperas and the agency started testing a small trawl for shrimp. In 2009, while small trawl experiments continued, WWF and INAPESCA started testing traps and longlines in combination with Fishing Aggregation Devices (FAD). From 2009 to 2013 INAPESCA conducted several tests with the prototype net including tests in nighttime and daytime, during the shrimp season and before the shrimp season, both with the original design and with modifications. In 2012, WWF and INAPESCA tested six different options for finfish fisheries. Finally in 2013 the small trawl was prescribed as part of the Mexican Standard for shrimp fishing.

SMALL TRAWL FOR SHRIMP

The small trawl for shrimp was developed by the National Institute of Fisheries (INAPESCA). This small trawl has several devices that improve its environmental performance: (1) turtle excluder device, (2) one fish excluder device, (3) double rope to avoid damaging the seabed, (4) progressive reduction in the mesh size along the net, (5) hydrodynamic trawl doors to reduce resistance and increase efficiency and (6) super-light materials.

Performance of the small trawl varies depending in the skills of the fishermen, season and fishing grounds. Its performance in optimal conditions has never been proven because this small trawl cannot be operated in the presence of gillnets. Tests in daylight during the shrimp season resulted in low performance because of the presence of gillnets (INAPESCA, 2011); tests during nighttime, absent gillnet interference, resulted in good catches of brown shrimp, which are only available at night but command lower prices than the highly desirable blue shrimp (INAPESCA, 2011); and tests before opening of the shrimp season resulted in catches of small-sized shrimp because those are what is available at that time of the year. This last test showed a good performance: 9.7 kg of shrimp per cast vs. 8.6 kg of by-catch (INAPESCA, 2012).

In 2013, the Mexican government mandated the use of the small trawl for the Upper Gulf of California shrimp fishery, with a phased approach over three years: removal of 30% of gillnet-equipped pangas in the first year, 30% in the second year and 40% in the third year. Even though this mandate represents an important step for the technological transition, significant challenges remain, among them: (1) **the small trawl cannot operate in the presence of gillnets,** (2) fishermen are reluctant to change, (3) fuel consumption and engine depreciation are higher with the small trawl than with gillnets, (4) it has not been demonstrated that the small trawl works in the eastern part of the Upper Gulf (Golfo de Santa Clara area), (5) administrative procedures in fisheries take time to develop and change, but in the present circumstances there is no time left for things to change in the normal fashion, (6) under optimal conditions (daylight, during the season and without gillnets present) the small trawl could be as profitable as the gillnet fishery, and (7) bycatch of juvenile finfish could be a concern.

A group of 17 fishermen from San Felipe has been working with the small trawl and participating in tests of other alternative technologies. This group of fishermen has important skills in the use of the small trawl and obtained good shrimp catches with it; these fishermen represent a very important asset given their ability to demonstrate the profitability of fishing with the small trawl, to train other fishermen, and generally to make the case in favor of the technological transition. They agree with technology experts that the gasoline-powered outboard engines currently used by fishermen are not the best way for using the trawl net, and that diesel-powered engines could improve the performance of the small trawl.

Finally, with gillnets in the water there is no way that the trawl fishery could be developed, regardless of the engine type or the skills of the fisherman. **With gillnets in the water, the small trawl will not work**.

DIESEL-POWERED SMALL VESSEL FOR TRAWLING

Fishermen, technology experts and naval engineers all agree that the small skiffs with gasoline outboard engines are not the best technology for using a trawl net. Three different models for a diesel-powered small trawl vessel were presented during CIRVA meeting.

The first proposal was a 30-foot vessel with a stationary diesel engine and capacity for three people. This vessel would have a cost of about 130,000 USD for the first prototype and around 15% less thereafter. Ideally this kind of vessel should land at a dock, but it could also land on the beach. It would give fishermen more autonomy and range, greater towing depth and power, and enable longer cast and journey times. With this kind of vessel, the fishing power would increase. Therefore it would be very important to consider sustainability of the shrimp fishery itself if this technology were to be selected.

The second and third proposals were presented by fishermen from the Upper Gulf, taking into account the socio-economic circumstances there. The proposed vessels are smaller in length and weight and are designed to land on the beach and be transported to the home of the fishermen every day. The cost of each of these proposals is around 50,000 USD, i.e. considerably lower than the first one. The two proposals include a 200HP diesel engine. However, current regulations limit the engine power to 115 HP. This is a challenge that would need to be addressed if either of these models were to be selected.

The information presented at this meeting was not sufficient for making any recommendation about the best vessel design. Some similarities, however, such as the vessel size (27-30 feet) and the engine type (stationary diesel), show that different people are thinking along similar lines in the search for a best design.

ANNEX 4: ALTERNATIVE TECHNOLOGIES AND FISHERIES

LINES AND TRAPS

The small trawl for shrimp is a good solution for the shrimp fishery, but most fishermen in the Upper Gulf make a living from two main seasons: the shrimp season (September to March) and the finfish season (March to July). For the finfish season, traps and longlines have been tested (Table A.1). Rectangular traps proved to be very efficient but their dimensions were too large for the skiffs used in the small-scale fisheries in the Upper Gulf; thus some additional research has been done (but more is probably needed to develop a collapsible rectangular trap.

Table A.1

Results of tests of lines and traps in 2012

	Total Catches (kg)	Catches		By-catch Ratio
		per unit	per hour	
Collapsible traps	2.30	0.58	0.13	1 : 0.00
Rectangular traps	243.28	4.96	2.76	1 : 0.09
Longline	19.00	0.05	3.17	1 : 1.36
Conical traps	6.00	0.21	0.24	1 : 0.50
Octopus traps	3.30	0.22	0.41	1 : 0.06
Crab traps	7.90	0.18	0.21	1 : 2.13

***Source:** INAPESCA, WWF, 2012.*

Longlines have also been tested commercially. The longline fishery in the Upper Gulf has existed for a long time, but it has always constituted a very small proportion of the overall fisheries. PRONATURA has been working with a group of 15 longline fishermen to understand the costs and benefits of longline fishing. In 2013, PRONATURA analyzed 136 journeys of these fishermen. The total operation costs of these journeys amounted to 20,000 USD, of which 11,600 USD consisted of payments to fishermen for labor; the benefits amounted to about 28,000 USD over a period of three months. Therefore, the benefit-cost ratio was 1.4 over that period.

Despite the good benefit-cost ratio, there are some challenges for extending the use of longlines in the region, among them: (1) longline fisheries capture different species than gillnets and are used to supplement income and not as a main earning activity, (2) the good season for the species captured with longlines overlaps with the seasonal shark fishing closure, (3) the revenue obtained from three days of fishing with longlines can be obtained from just one day of gillnet fishing , (4) longlines capture specimens of premium quality ('de primera') but domestic markets that would pay reasonable prices for such products do not exist in San Felipe, and (5) neither longlines nor traps capture the same array of species as gillnets or the same quantities of products as gillnets. In the case of traps, there are other important challenges including: (6) fishermen don't like the high selectivity of traps so there is likely to be some opposition to any switch to trap fishing and (7) the presence of gillnets interferes with the operation of traps and therefore as long as gillnets are in the water, it is unrealistic to think a trap fishery can be developed.

During the CIRVA meeting ideas were presented for dealing with some of those challenges. For example, PRONATURA suggested working with international markets and exploring added-value options in order to find (or create?) good prices for the longline and trap fisheries. Fishermen present at the meeting suggested that tests of traps for finfish should be continued.

An important concern was raised about the use of longlines in or near the range of totoaba. However, it was reported that not a single totoaba was observed during the longline experiment conducted by PRONATURA. Also, according to the fishermen present at the meeting, the size of the hook and the bait used for sand sea bass and groupers are very different than what is needed to catch totoaba.

ALTERNATIVE FISHERIES

According to the National Fishing Chart (Carta Nacional Pesquera, 2010), some species of shellfish in the Upper Gulf are 'under-exploited' (i.e. exploited at rates below what would provide the Maximum Sustainable Yield, MSY) and can support an increase in fishing effort, mainly in the waters near San Felipe and El Golfo de Santa Clara.

Some fishermen have moved into fisheries for these shellfish species in recent years. Such fisheries do not involve the use of gillnets and they therefore represent opportunities for 'swap outs'. In 2009 the first permits for these species were issued as part of a swap-out program led by the Mexican Government under which some fishermen surrendered their gillnet permits in order to start exploring the alternative shellfish fisheries. Among the species considered to have development potential and that could be used to swap-out gillnets are geoduck, clams, rock scallop, murex and oysters. A reduction in the gillnet fishery could spur increased effort in these fisheries.

Fisheries for some of the shellfish are particularly suited to the Upper Gulf and have no by-catch and low ecological impact, and the target species grow quickly and can be harvested year-round. The demand for some of the species in international markets has been increasing and some of them could be produced with aquaculture techniques. Processing to give added value should be relatively easy. It is nonetheless difficult to find fishermen who are willing to exchange their gillnet permits for shellfish permits. Among the reasons for this are: (1) obtaining the legal permits could take a long time, (2) the requirements for technical studies could lead to considerable expense and (3) the international market for some of them, e.g. geoduck, is decreasing. Without knowing the levels of effort required to exploit new species and without having reliable information on allowable catches, fishermen are reluctant to switch to these alternative fisheries or to explore marketing opportunities.

Regardless of the challenges mentioned above, some of these fisheries are, or could be, very profitable. One of the first participants in the geoduck fishery summarized his experience for meeting participants. The business has been highly profitable for him and he is now re-investing in a laboratory for producing geoduck 'seed'.

ANNEX 4: ALTERNATIVE TECHNOLOGIES AND FISHERIES

CONCLUSIONS

The session on alternative technologies and fisheries provided considerable information related to fishing gear and techniques. Among the highlights are the following:

- After years of research, technologies and methods are available that make it possible to maintain fisheries in the Upper Gulf without dependence on gillnets.
- The majority of the fishermen are reluctant to change.
- There is a group of committed, skilled fishermen who are using the small trawl commercially and demonstrating that it is possible to making a living using this gear.
- Small trawls and fish traps are not compatible with gillnets in the same area at the same time; so the absence of gillnets will favor and promote the adoption of these new technologies.
- The use of diesel-powered engines will increase the efficiency of the small trawl.
- Based on the studies and data presented, longlines are being used profitably in the Upper Gulf, but less revenue is obtained from longlining than from gillnetting.
- There are alternative fisheries in the Upper Gulf that could be even more profitable than fishing with gillnets (for example shellfish fisheries), but fishermen often opt for the easiest, most familiar and thus 'safest' option, which is to continue fishing with gillnets.
- In all cases, opening new fisheries, catching different species with longlines and using trawls for shrimp, authorities should pay special attention to the available biomass and ensure that changes in fishing effort do not lead to overfishing.
- A well-enforced ban on gillnets could accelerate the technology change.

Annex 5: Review of progress with past recommendations

Table 1

Review of progress towards implementation of measures previously recommended by CIRVA and/or PACE-Vaquita. The subjective judgment categories under "Progress" are: H = high, M = Medium, L = Low, N = None (with the Success rating given in **2014 in bold**, 2012 in italics and 2004 CIRVA report in parentheses). Colors indicate: black--recommendation from CIRVA II and still relevant, red--recommendation of CIRVA II but current recommendation differs, blue-- recommendation of CIRVA IV. *Not discussed during CIRVA V

Recommendation	Current situation	Progress (H,M,L,N)
1. The by-catch of vaquitas must be reduced to zero as soon as possible.	Evidence suggests that fishing effort has not been significantly reduced and bycatch has not been reduced to zero. The decline of 18.5%/year indicated by the acoustic monitoring means that the by-catch rate estimate is the highest ever estimated.	**N** *L* (N)
2. The southern boundary of the Biosphere Reserve should be expanded to include all known habitat of vaquita.	The Vaquita Refuge, initiated in 2005, covers part of the range to the south, but not all. Fishing effort along the southern border of the Refuge where high densities of vaquitas are known to occur outside the Refuge is very high.	**N** *M* (N)
3. Gillnets and [industrial] trawlers should be banned from the Biosphere Reserve, in the following sequence:		
Stage One (to be completed by 1 January 2000) • Eliminate large-mesh gillnets (6-inch stretched mesh, or greater); • Cap the number of pangas at present levels; • Restrict fishing activities to residents of San Felipe, El Golfo de Santa Clara, and Puerto Peñasco.	• Large-mesh gillnets banned in the Biosphere Reserve in 2002 and have not been used since 2007. Resurgence of the toatoaba fishery in 2011 means large-mesh gillnets are currently back in use • In 2012 the number of pangas has been reduced and capped (but probably at a level that still is similar to or exceeds the number of pangas in 2000). Evidence from aerial surveys indicates relatively level numbers of pangas but new and 'cloned' pangas are reported in recent years. Progress has been made in restricting fishing activities to local permitted pangas and trawlers. This restriction has been enhanced through requirements to conform to Environmental Impact Statements to fish in the reserve. Pangas from outside the three communities of the Upper Gulf have been reported fishing in the area.	**N** *M* (M)
Stage Two (to be completed by 1 January 2001) • Eliminate medium-mesh gillnets (i.e. all except chinchorro de linea).	Reduced within Vaquita Refuge though violations are frequent. Reductions have also occurred through the program to switchout from gillnets to vaquita-friendly gear (e.g. longlines and pots). However, success rating is Low because effort with medium-mesh gillnets remains high in areas outside the Refuge where approximately half of vaquitas can be found.	**L** *L*[1] (L)

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[1] CIRVA members feel that the past success rating should have been N, and that progress has been made on this recommendation.

ANNEX 5: PROGRESS WITH PAST RECOMMENDATIONS

Recommendation	Current situation	Progress (H,M,L,N)
Stage Three (to be completed by 1 January 2002) - Eliminate all gillnets and [industrial] trawlers.	Reduced gillnetting within Vaquita Refuge though violations are frequent. Industrial trawling within the Refuge is nearly eliminated. However industrial trawling has not been eliminated. Rating is also Low because effort with chinchorro de linea gillnets remains high in areas outside the Refuge where approximately half of the vaquitas can be found.	**L** *L*[2](L)
PACE eliminate gillnets throughout the range of vaquitas by 2012	Reduced within Vaquita Refuge though violations are frequent. Rating is Low because effort remains high in areas outside the Refuge where approximately half of the vaquitas can be found.	**N** *L*
4. Effective enforcement of fishing regulations should begin immediately. The development of effective enforcement techniques should be given high priority because all of the committee's recommendations depend upon effective enforcement.	Previous progress was made in terms of permits and reduction of un-permitted fishing. Trawlers are required to carry location devices (VMS). The Vaquita Refuge has been marked with buoys. Fishing (gillnetting and trawling) within the Vaquita Refuge has likely been reduced since 2008. However, violations of limits on the length and number of nets/boat are widespread, have occurred for many years, and are a serious concern. Illegal fishing within the Vaquita Refuge is not uncommon. The resurgence of the totoaba fishery makes clear the lack of effective enforcement.	**N** *M*[3] (M)
5. Acoustic surveys should start immediately to (a) begin monitoring an index of abundance and (b) gather data on seasonal movements of vaquitas.	Acoustic surveys were done by Jaramillo-Legorreta from 1997-2007 and data indicated a decline in abundance and no evidence for seasonal movements. Results from 2011-2013 provide strong evidence of a serious decline (18.5%/year)	**H** *H* (H)
6. Research should start immediately to develop alternative gear types and techniques to replace gillnets.	Shrimp pots and suriperas were tested and failed. Several small shrimp trawls (RS-INP-MX) were tested and are viable fishing alternatives. Fin-fish traps are in an early testing phase. Other alternatives (long-lines, shellfish capture by diving) have been developed.	**M** *M*
*7. A program should be developed to promote community involvement and public awareness of the importance of the Biosphere Reserve and the vaquita, stressing their relevance as part of México's and the world's heritage. Public support is crucial.	The Assessment and Monitoring Board (Organo de Evaluación y Seguimiento, 2008) was formed and includes: fishermen from San Felipe, Golfo de Santa Clara and Puerto Peñasco, academics from Baja California and Sonora states, state and federal governmental institutions from fisheries and environmental sectors and NGOs. The EIA for small-scale fishing in the Upper Gulf provides a structure for continued progress on this.	* *H* (H)
*8. Consideration should be given to compensating fishermen for lost income resulting from the gillnet ban.		

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[2] Same comment as footnote 1.
[3] CIRVA members feel that the past success rating should have been L, and that progress has been made on this recommendation.

ANNEX 5: PROGRESS WITH PAST RECOMMENDATIONS

Recommendation	Current situation	Progress (H,M,L,N)
*Buy-out	247 artisanal boats with 370 fishing permits out of the water (numbers from http://www.conanp.gob.mx/vaquita_marina/)	*M*
*Biodiversity conservation actions	An average of 230 boats received compensation not to fish within the Vaquita Refuge Area (1,263 km^2) (http://www.conanp.gob.mx/vaquita_marina/). A Medium success rating was given in 2012 because fishing within the Refuge is frequent and the overlap between violators and those receiving compensation is unknown.	*M*
*Switch-out	230 pangas (including 247 permits) (http://www.conanp.gob.mx/vaquita_marina/) have participated in the switch-out to alternative 'vaquita-safe' fishing gear (in most cases presumably small trawls). A Low success rating was given in 2012 because of uncertainty about whether all 230 pangas were actually using the alternative gear provided. It is unclear whether they could use small trawls effectively on the fishing grounds given the high density of gillnets, which are obstacles to trawling. There is also uncertainty of whether CONAPESCA has provided the permits to use the alternative gear.	*L*
9. Research should be conducted to better define critical habitat of vaquitas, using data collected during the 1997 abundance survey.	Additional data gathered from both Vaquita Expedition 2008 and acoustic monitoring have been used effectively to delimit the total current distribution of vaquitas. Acoustic monitoring within the Refuge reveals some shifts in distribution between mid-June and mid-September but no progress has been made to monitor outside the Refuge	**M** *H* (M)
10. The international community and NGOs should be invited to join the Government of México and provide technical and financial assistance to implement the conservation measures described in this recovery plan and to support further conservation activities.	International organizations (Commission for Environmental Cooperation), NGOs (WWF and Cousteau Society) the governments of the US (NOAA Fisheries and the Marine Mammal Commission) have worked as active partners with the Government of Mexico towards the conservation of the vaquita and the ecosystem of the Upper Gulf. WWF Mexico and PRONATURA have provided excellent support to fishermen trained to use the small-trawls. CEDO has worked with fishermen in recording fishing effort for environmental impact assessments.	**H** *M* (M)

ANNEX 6: GILLNET EXCLUSION ZONE RATIONALE

Annex 6: Rationale for the proposed gillnet exclusion zone

The primary objective of the gillnet exclusion zone is to encompass the complete current range of vaquitas. The secondary objective is to delimit the zone in such a way that it is easy for both fishers and enforcers to know when activities are within or outside the zone both visually and with a GPS.

The range of vaquitas is known from several sources: 1) skeletal remains, 2) reports of vaquita deaths in fisheries, 3) dedicated surveys (both visual and acoustic).

Brownell (1986) summarized confirmed stranded remains of vaquita which were mainly bones and found no confirmed remains to the south of Puertecitos along the western side or south of Puerto Penasco on the eastern side. Reports from fisheries show extensive captures in shallow-water areas (Fig. 9.1 from Gallo-Reynoso, 1998).

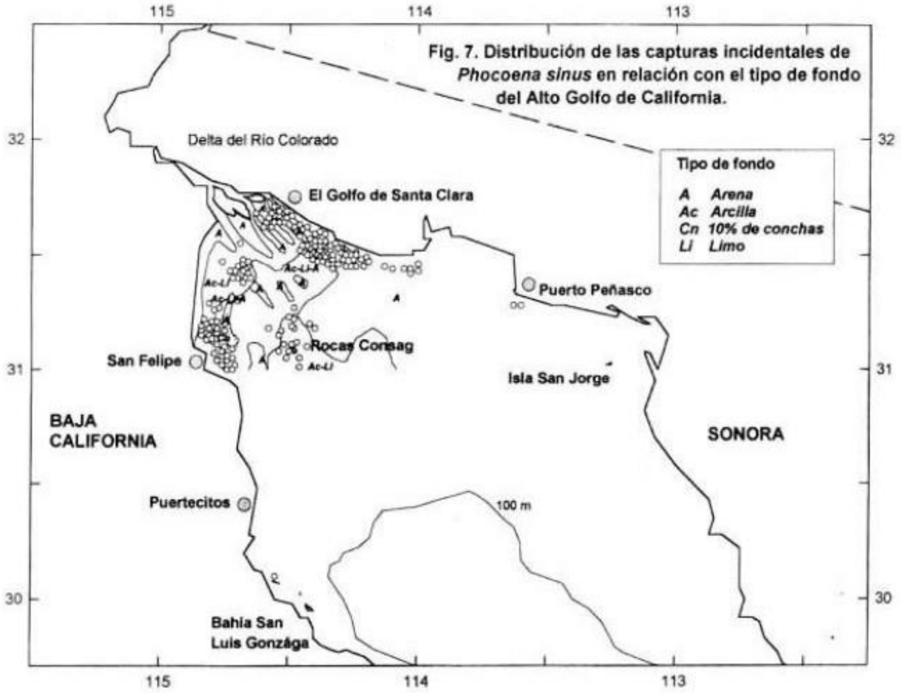

Figure 1. Distribution of incidentally captured vaquitas in relation to the type of bottom in the northern Gulf of California. Key for bottom types with English in parentheses: A = arena (sand), Ac = Arcilla (clay), Cn = 10% de conchas (10% shells), Li = Limo (silt).

Observations and interviews from El Golfo de Santa Clara that were used to estimate vaquita mortality rates also suggest these shallow water areas as important vaquita habitat (D'Agosa et al. 2000). Their description of vaquita distribution suggests vaquita presence in all the fishing grounds shown in the figure below.

ANNEX 6: GILLNET EXCLUSION ZONE RATIONALE

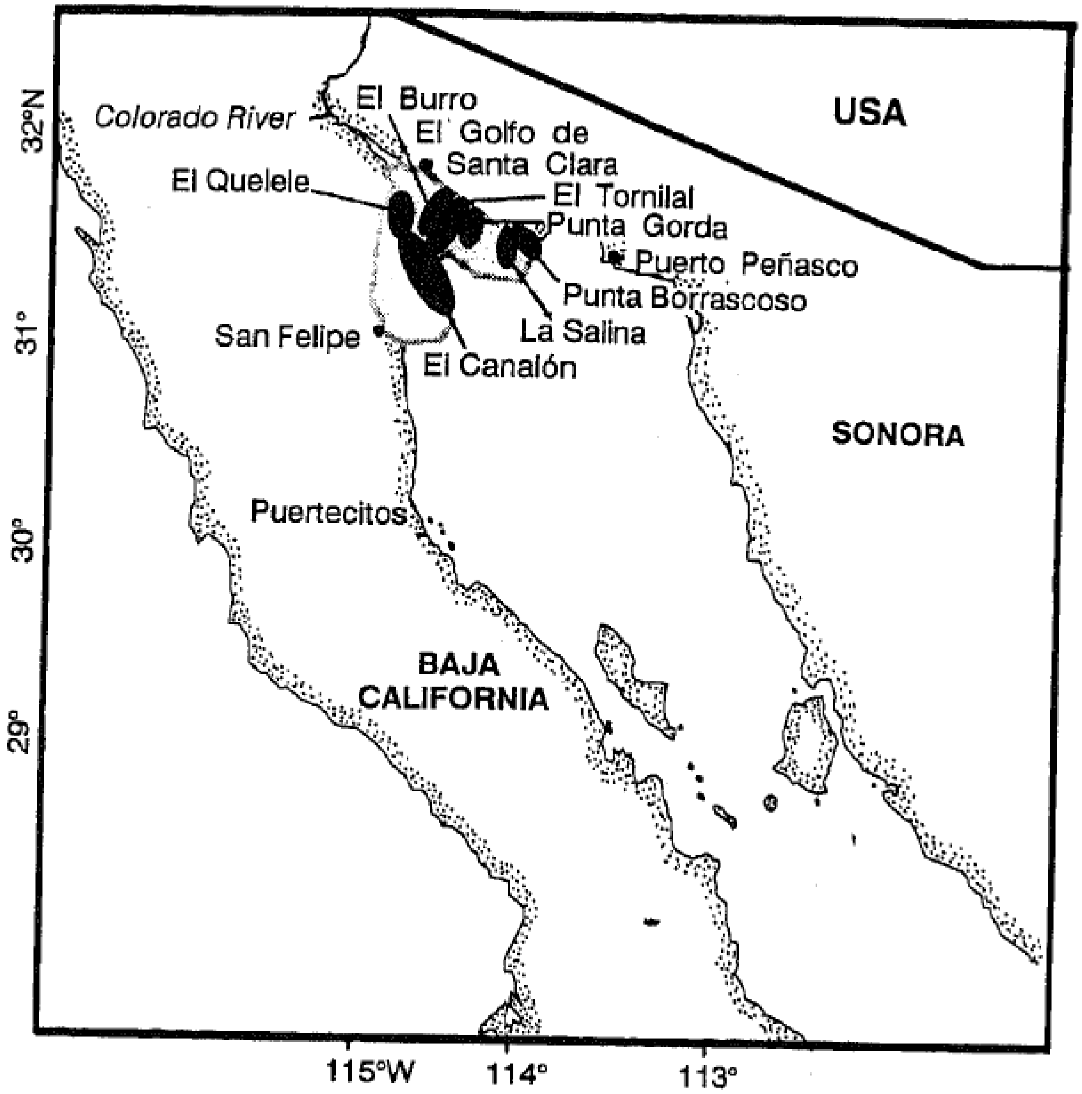

Fig. 1. Study area. Preferred fishing grounds in black, 23 January 1993–29 March 1994.

Figure 2. Fig. 1 taken from D'Agrosa *et al*., 1995 which shows the preferred fishing grounds for El Golfo de Santa Clara. Vaquita were killed in all these fisheries. Note that data come primarily from January to March.

Visual and acoustic surveys give a different impression of vaquita distribution for two possible reasons: 1) data come primarily from September through November (visual) or mid-June through mid-September (acoustic), and 2) the vast majority of effort is for the deeper water areas where the large ship could navigate or where passive acoustic devices could be protected from gillnet and trawl removal within the Vaquita Refuge. The vaquita detections shown in Figure 9.3 result from effort focused on the deeper waters navigable by ship with very little effort in the shallow water areas covered by the fisheries information above. All detections in the figure have high reliability for being vaquita (Barlow et al. 1997, Jaramillo et al. 1999, Gerrodette et al. 2011). The southernmost point was a sighting made by Barlow and Forney on an aerial survey (Barlow et al. 1993). Both are experienced porpoise observers. One sighting from south of Puerto Penasco was excluded from consideration because it was made from a helicopter and displayed jumping behavior not observed in vaquita. Another sighting off Isla Montegue was excluded because it was from an aerial survey with a group size of well over ten individuals, which was also deemed unlikely to be vaquita.

An additional line of evidence for the Gillnet Exclusion Zone including the western and northern shallow water zones down to about Puertecitos comes from the apparent preferred habitat of vaquita over muddy seafloors resulting from deposition from the Colorado River (Gallo-Reynoso, 1998). The sedimentation pattern in this area is shown in Figure 9.4 (from Carriquiry et al. 2001). Deposition of the fine mud that suspends in the waters above as tidal currents flow down the western portion of the Gulf.

Boundary lines were chosen to both encompass know current vaquita distribution and to be as simple as possible to implement for fishermen and enforcers. Thus, a single reading on a GPS device will determine whether you are north of 30º05'42" (which could be seen visually as the north tip of "Isla el Muerto") or west of 114º01'19" (which could be seen visually as Punta Borrascosa). If either of those conditions are true, then no gillnets are allowed (whether on land or at sea).

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ANNEX 6: GILLNET EXCLUSION ZONE RATIONALE

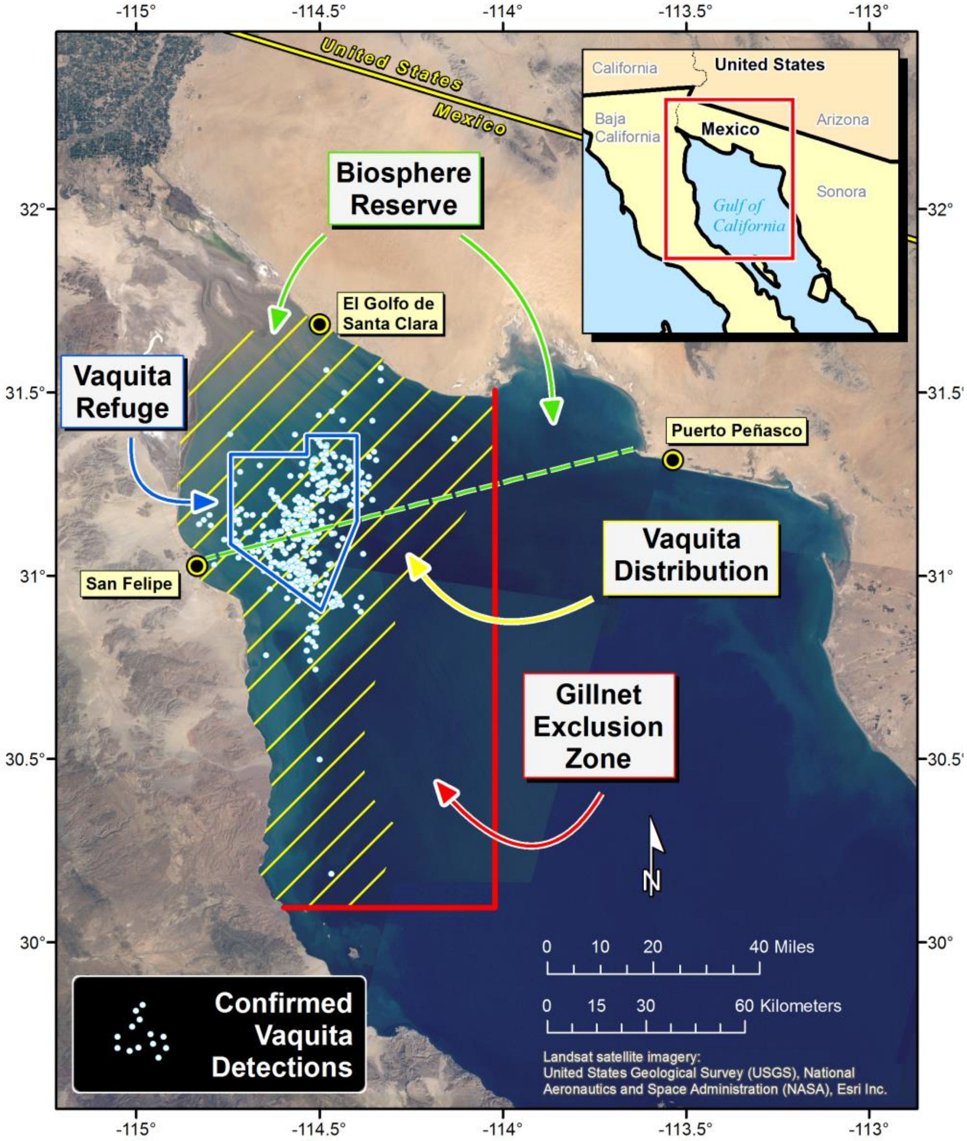

Figure 3. Gillnet exclusion zone proposed at fifth meeting of CIRVA. Red lines delimit the proposed gillnet exclusion zone. The southeast vertex of this zone, where both straight lines intersect, is at 30º05'42"N, 114º01'19"W. From this point a line extends to the north towards 'Punta Borrascosa' (Borrascosa Point). The other line extends to the west until it meets the coast of Baja California, passing along the northern tip of 'Isla el Muerto' (El Muerto Island, the northernmost island in Las Encantadas Archipelago). Gillnet exclusion zone boundaries were chosen for ease of use by fishermen and enforcement agents. A simple GPS reading or line of sight to well-known land markers can be used. The proposed gillnet exclusion zone is intended to include the full known range of vaquitas since the 1990's using data from fisheries and some survey locations for distribution in the shallow water areas and from the visual and acoustic detections (visualized with white dots) in the deeper waters. The area also encompasses the habitat with muddy waters (seen in the satellite image) created by strong currents that comprise critical habitat for vaquitas.

ANNEX 6: GILLNET EXCLUSION ZONE RATIONALE

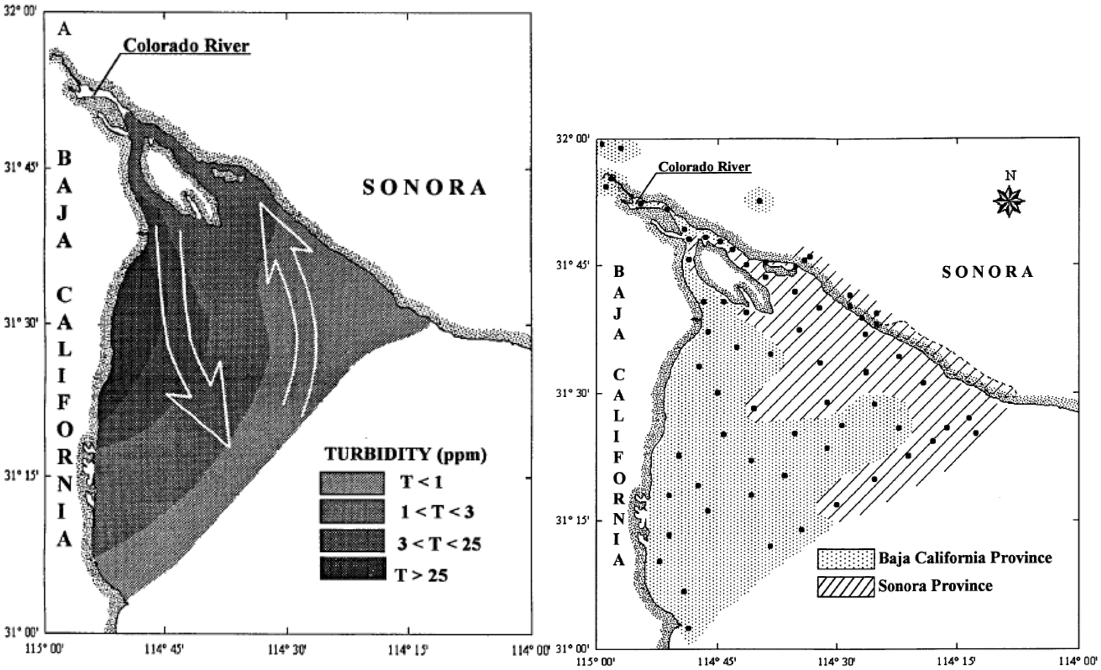

Figure 4. Spatial variability pattern of turbidity and sedimentary provices obtained by Q-mode cluster analysis from Carriquiry *et al*. 1999.

ANNEX 7-9: ACOUSTIC MONITORING PROGRAM

The following Annexes 7 – 9 are reports of meetings related to the acoustic monitoring program completed before CIRVA-V and reviewed at CIRVA-V. They are page numbered independently of the CIRVA-V report.

Annex 7: VAQUITA POPULATION TREND MONITORING SCHEME BASED ON PASSIVE ACOUSTICS DATA - PROGRESS REPORT FOR STEERING COMMITTEE – 19pp.

Annex 8: SECOND MEETING OF THE STEERING COMMITTEE OF THE VAQUITA ACOUSTIC MONITORING PROGRAM – 50pp.

Annex 9: EXPERT PANEL ON SPATIAL MODELS: REPORT ON VAQUITA RATE OF CHANGE BETWEEN 2011 AND 2013 USING PASSIVE ACOUSTIC DATA – 50pp.

VAQUITA POPULATION TREND MONITORING SCHEME BASED ON PASSIVE ACOUSTICS DATA

PROGRESS REPORT FOR

STEERING COMMITTEE

SECOND MEETING

Ensenada, B.C., México
April 24-25, 2014

CONTENTS

1. Introduction

This report presents partial results of an investigation aimed at estimating the population trend of the vaquita, through monitoring of individuals of the species with passive acoustic techniques, as designed by a group of experts (Rojas Bracho et al., 2010).

This monitoring scheme is based on the installation of autonomous acoustic detectors, named C-POD, at 48 sites within the Refuge for Protection of Vaquita and buoys used to delimitate it. Given illegal fishing activities that happen inside the refuge, the 48 sampling sites were restricted to the three months before the shrimping season (June to September) when fishing intensity is the lowest of the year. Efforts have been made to continue sampling all year-round with detectors deployed in the buoys. However, we have experienced loss rates that are not sustainable. This report describes the different alternatives of mooring methods essayed that have failed, as well as a recent attempt to solve this problem.

In its current development, the monitoring scheme envisages the attainment of six years of sampling, in order to detect small increases or decreases of the population during this period. This information is essential to adjust the actions taken by the Mexican government to recover the species. If population is not monitored directly, given its critical current level, it could reach very low numbers before the recovery program is adjusted in a timely manner.

This report presents data obtained during the first three years of sampling, and depicts the analysis done until now. It includes the identification of vaquita acoustic events and the implementation of a model to estimate the acoustic encounter rate trend in relationship with time, as an index of population trend.

2. Field activities

2.1. Acoustic detectors deployed on delimiting buoys of Protection Refuge

The only feasible way to gather acoustic data all year round, in order to understand distribution patterns of vaquita acoustic activity, is to deploy acoustic detectors in the buoys delimiting the Protection Refuge (Figure 1A). Until now three mooring methods have been essayed, all with poor results in terms of equipment recovery.

The first method (Figure 1B) consisted in a metallic frame attached to the buoy chain, which was the platform to moor the acoustic detector. Using this method 13 moorings were deployed on July (6) and September 2011 (remaining 7), in buoys 1, 2, 3, 5, 6, 7, 8, A, B, C, F, G and I (Figure 1A). Buoys 4, D and E were not in place previous to deployment. During December 2011 and January 2012 it was tried to retrieve the acoustic detectors. At first, according to plans, it was tried to grasp the line holding the detector (Figure 1B) with a hook inserted in the tip of a pole. This was successful only at Buoy 8. Further inspection using submersible camera and diving evidencing interaction with fishing or directed sabotage, finding no frames or frames detached of the chain, as well as entangled gillnet pieces (Figure 1C). Diving in the buoys resulted in the recovery of an additional detector in Buoy 2. Fishermen delivered later the acoustic detectors deployed in buoys 1 and A. Hence, only one out of 13 detectors was recovered in the proper way.

After the failure of the method described above, it was essayed to mooring acoustic detectors directly to the buoy chain using a snap shackle (Figure 1D). This was made by SCUBA diving. During this activity it was possible to check the buoys for the situation of the moorings described above. During January 31st and February 1st, 2012, twelve detectors were deployed at buoys 1, 2, 3, 5, 6, 7, 8, A, B, F, G and I. Buoy C was not in place, in addition to ones at sites 4, D and E. On March 23rd, almost two months after deployment, it was possible to recover the detector at Buoy G, which was replaced by another with fresh batteries. On April 28th it was tried to recover detectors at buoys 2, 3, 5, 6, B and I, recovering only the one at Buoy 5, finding again evidences of fishing operations or directed theft. In fact the recovered detector was entangled in several folds of a net. Buoy F was removed for maintenance by PROFEPA, which delivered the detector deployed there to Biosphere Reserve. The one deployed at Buoy 8 was found by Biosphere Reserve personnel floating nearby. During May it was unsuccessfully tried to recover the reminder detectors at buoys 1, 7, A, B as well as the one redeployed in Buoy G during March. Summarizing, not accounting for Buoy F, it was possible to recover detectors only on two of the eleven buoys, although the detector redeployed at Buoy G was finally lost.

The mooring method depicted above was of difficult implementation, as it is needed diving to deploy and retrieve detectors. An alternative method is depicted in Figure 1E. A rope is attached to the weight holding the buoy and is hold extended with an anchor, where another rope is used to hold the acoustic detector. The rope is extended inside the Protection Refuge. The installation of the rope in the weights is not a job for amateurs, since it is a deep diving under extreme turbidity. As such, it was required the hiring of professional divers. To retrieve detectors a hook is towed behind a boat to grasp the rope and pull it to reach the detector. This method is thus similar to that used in the moorings that are deployed within the refuge (see next section). However, it will be not required to waste time searching for the rope with GPS positions, because the buoy marks the position clearly.

During September 7 to 9, 2012 (just previous to shrimp season), 11 moorings were placed on buoys 1, 2, 3, 5, 6, 7, 8, A, I, F and G (Figure 1A). The field operations team worked together with the divers. Once the diver went down and attached the rope to the buoy, a small boat was used to extended rope, into the Refuge, and threw the anchor along with the acoustic detector. The team stayed at the site for several minutes to ensure that all the rope gets submerged, without any sign on the surface.

Some days after the deployment PROFEPA removed buoys A and I for maintenance and bring back acoustic detectors, which gather, respectively, only 6 and 14 days of data. Efforts to recover the acoustic detectors were done first on November 22nd and five of the moorings were properly grasped and detectors retrieved (buoys 2, 5, 6, 8 and F). On December 14th one additional detector was retrieved at Buoy G and few days later a fisherman delivered the detector deployed at Buoy 7. Moorings at buoys 1 and 3 were not located after about two hours of searching effort. Hence, not accounting buoys A and

I, six out of the nine detectors deployed were properly located and retrieved, even in areas subjected to intense fishing operations.

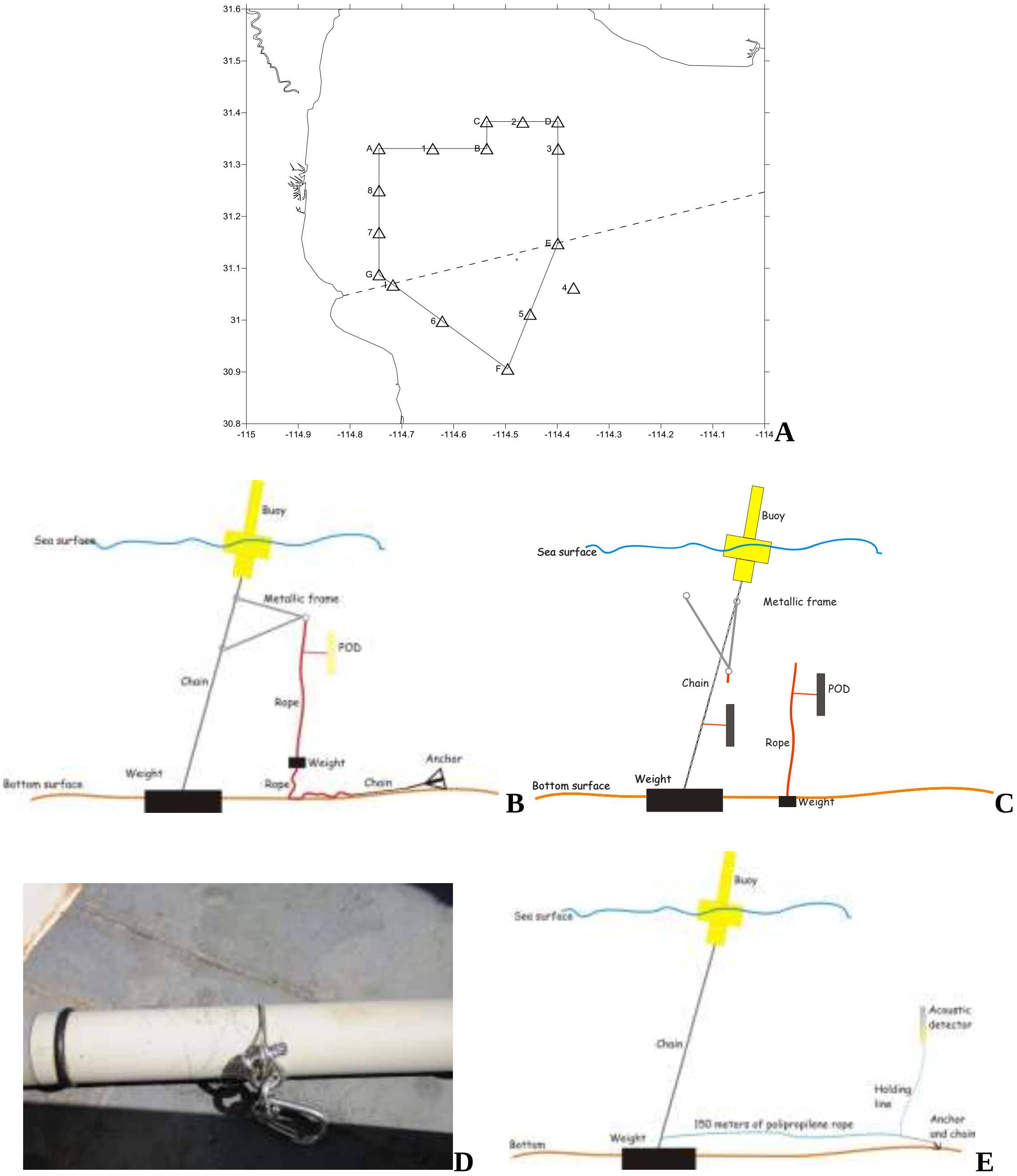

Figure 1. A) Map showing the polygon of Vaquita Protection Refuge (solid line) and delimiting buoys (triangles). Broken line represents the seaward boundary of the Biosphere Reserve. B) First method to deploy acoustic detectors on buoys. C) How first method failed and way to mount detectors directly to buoy chain. D) Shackles used to mount CPOD to chain. E) Method to mooring detectors using a long rope attached to buoy weight.

After December 2012, detectors with fresh batteries were deployed at the buoys where moorings were found (2, 5, 6, 8, F and G). Unfortunately, by March 2013 none of the detectors were found. Hence, although after the first retrieving period the mooring method looked promising, it is evident that we still do not have a robust method to sample all year round in buoys.

As it is important for the monitoring scheme to gather data about distribution of the acoustic activity of vaquita all year round, and the deployment in buoys looks as the only feasible way to do it, a fourth mooring method was essayed on March 11th 2014. The same approach depicted above (Figure 1E) was used, but replacing all the materials with stainless steel, without any hand removable parts, supposing ropes were cut on the past trials. A couple of moorings were deployed in buoys G and I using SCUBA diving, holding the wire at about 15 meters below the surface. As the wire must tend to get buried into the bottom sediments, holding the wire not as close the bottom as in the past trials could help to properly grasp the wire during equipment retrieval. No acoustic detectors were placed in the mooring, waiting to review if moorings stay in place intact.

On April 12th the moorings were inspected. The one deployed at Buoy I was found after four attempts to grasp the wire, passing relatively close to the buoy. The one at Buoy G was not found after several passes at different distances from the buoy. It will be required to dive in the site to determine if it was stolen, moved by fishing operations or not effective anchoring, or because the wire got buried too deep in the sediments. The pieces of the mooring deployed at Buoy I look in good shape after one month of service, confirming the quality of the stainless steel used (Figure 2).

After reviewing by diving the mooring at Buoy G, as well as to review again the one at Buoy I, it will be decided the next steps. In case to find that moorings are there, other ones will be deployed at other buoys to continue with the trial, but no actual detectors will be used until determine that the design can assure the recovery of them.

Figure 2. Detail of river anchor**,** wires and lock used to construct the moorings to deploy acoustic detectors in the buoys delimiting the Protection Refuge for Vaquita. After one month of soaking it do not appears any trace of stain or damage.

2.2. Acoustic detectors deployed inside Protection Refuge

The moorings used to deploy acoustic detectors inside Protection Refuge are alike the ones used to deploy in Refuge buoys (Figure 1E). A main polypropylene rope, about 150 meters long connects two anchors with chain at every side. One of them is Danforth style and the other river kind. On the side of the river one a rope is connected which holds a small rigid buoy and acoustic detector (Figure 3). A piece of chain is placed in the middle point of the main rope to hold against the bottom, as the material has positive floatation and during trials the rope was visible in surface on some occasions.

The procedure to deploy the mooring and detector starts by launching the Danforth anchor at the sampling site. At the same time the geographical position is recorded in a handheld GPS. Then the boat is moved to the east in order to extend the line until it is determined that the anchor is resisting the pulling. At that time the river anchor is launched together with the holding line and detector. Again, position is recorded in GPS. The retrieval of the moorings is done by trawling a grasping hook behind the boat, using to navigate the GPS positions recorded at the time of deployment.

After three years of sampling the field operations team (three boats) has developed enough skills to efficiently do the job. On deployment every boat carries seven or eight moorings per trip, so the job can be completed in two days. On retrieval every boat recovers approximately five moorings per day. The technique is so refined that finding of the mooring main line takes in average 20 minutes since deployment of hook until grasping. Took the mooring on the boat takes another 20 minutes using human and boat power. Hence, it is considered that mooring method used inside Protection Refuge is working well and is not necessary to change anything.

In 2011, first year of formal sampling inside Refuge, moorings and detectors were deployed in the 48 sampling sites designed during 2009 Workshop (Rojas Bracho *et al*., 2010; Figure 4) between June 5 to 9. Operations to locate and retrieve then were carried out between September 9 and 25. During the first two weeks 38 of the 48 moorings deployed were located and retrieved, one of them without the acoustic detector (Figure 4). A couple of detectors were delivered to the staff of the Biosphere Reserve previous to the start of recovery tasks (sites 2 and 9; Figure 4), therefore there was no search effort at these sites. The CPOD deployed at site 45 was delivered during January 2012. The one deployed at site 3 was recovered during the retrieval of equipment deployed during 2013 sampling season. Six of the moorings were never found.

On early May 2012, we obtained information about the presence of dozens of fishing boats within the Refuge, sighted during a survey flight[1]. Accordingly, it was decided to delay the deployment of detectors waiting for a reduction of fishing intensity. By June,

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[1] Juan Manuel García Caudillo. Project "Assessment of the effects of the productive and technological reconversion program PACE: Vaquita, on the number and space-temporal distribution inside the refuge for the protection of vaquita and Biosphere Reserve Upper Gulf of California and Colorado River Delta". Pesca Responsable y Comercio Justo S. de R.L. de C.V. Blvd. Zertuche 937-3, Valle Dorado, Ensenada, B.C., México 22890.

we were reported that only a few boats had been found, so it was decided to install the detectors by the middle of this month.

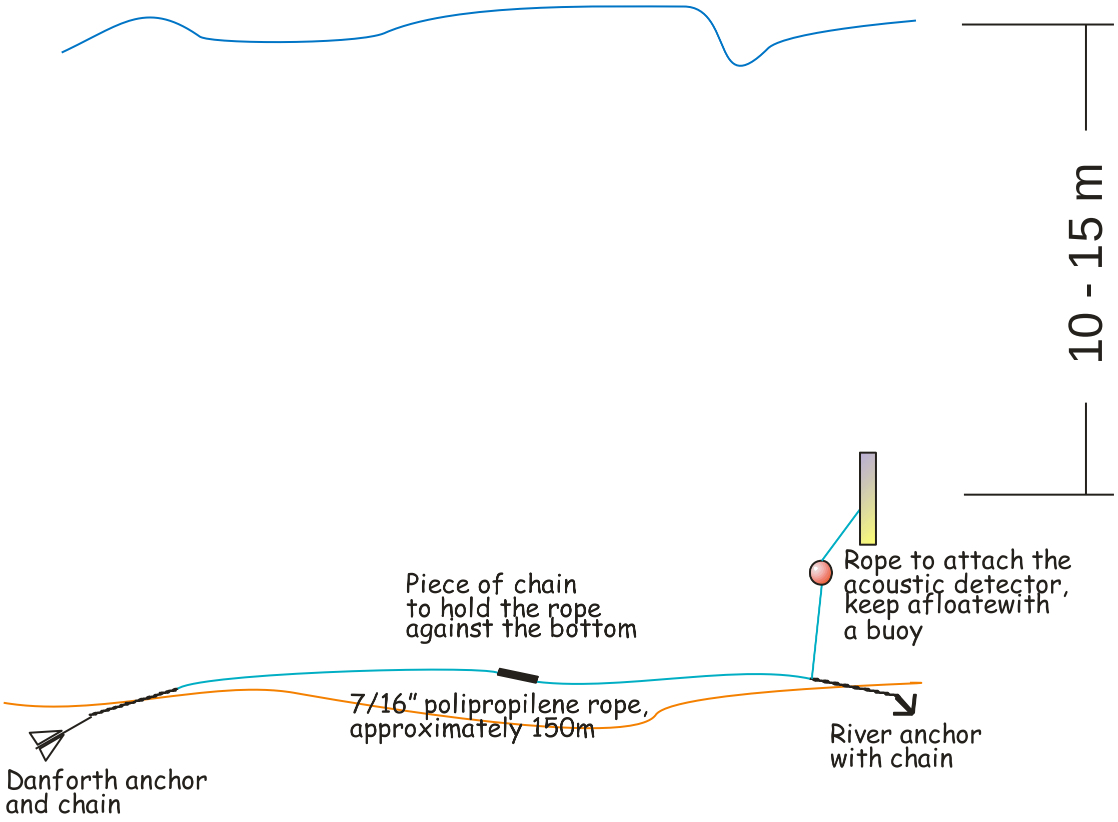


Figure 3. Sketch of the moorings used to deploy acoustic detectors inside Protection Refuge of Vaquita. The basic idea is to connect two anchors with a long rope that can later be grasped by means of a hook trawled behind a boat. No traces of the mooring are visible in surface in order to avoid theft. Location of anchors are marked in GPS that help later to know where to navigate to grasp the rope. A rope to hold the CPOS is attached to the side where river anchor is.

All 48 moorings of the monitoring scheme (Figure 4) were deployed between June 17 to 20. The field work to recover the moorings was carried out between September 17 and 22. A total of forty one moorings and detectors were recovered (Figure 3). One detector was delivered by a fisherman and the ones deployed at sites 11, 15 and 45 were recovered during the retrieval of equipment deployed during 2013 sampling season. As in 2011 sampling season, moorings at sites 17, 18 and 33 were not found.

It was decided not to deploy equipment at these sites during the 2013 sampling season, in order to avoid more equipment. Two of these sites are in the southwest boundary of the Vaquita Refuge and the other close to. Hence, frequent fishing operations could be the reason for the lost. After being informed of the reduction of fishing boats in the area, 34 moorings were deployed between June 15 and 16. Due to bad weather conditions the deployment of the reminder moorings took place on June 22 (7 moorings) and July 13 (4 moorings). The field work to recover the moorings was carried out between September 9 and 12. A total of 39 moorings and detectors were recovered (Figure 4). On

September 20 other detector was recovered. On October 1st, a coordinated effort of three boats working side by side to cover more area, resulted in the additional retrieval of four detectors. Of the 45 moorings deployed only the one at site 3 was not located, which represents a loss of only 2.22%. It is far the most successful sampling until now in regards to the loss of moorings in the field, not taking into account the three sites where no deployment occurred.

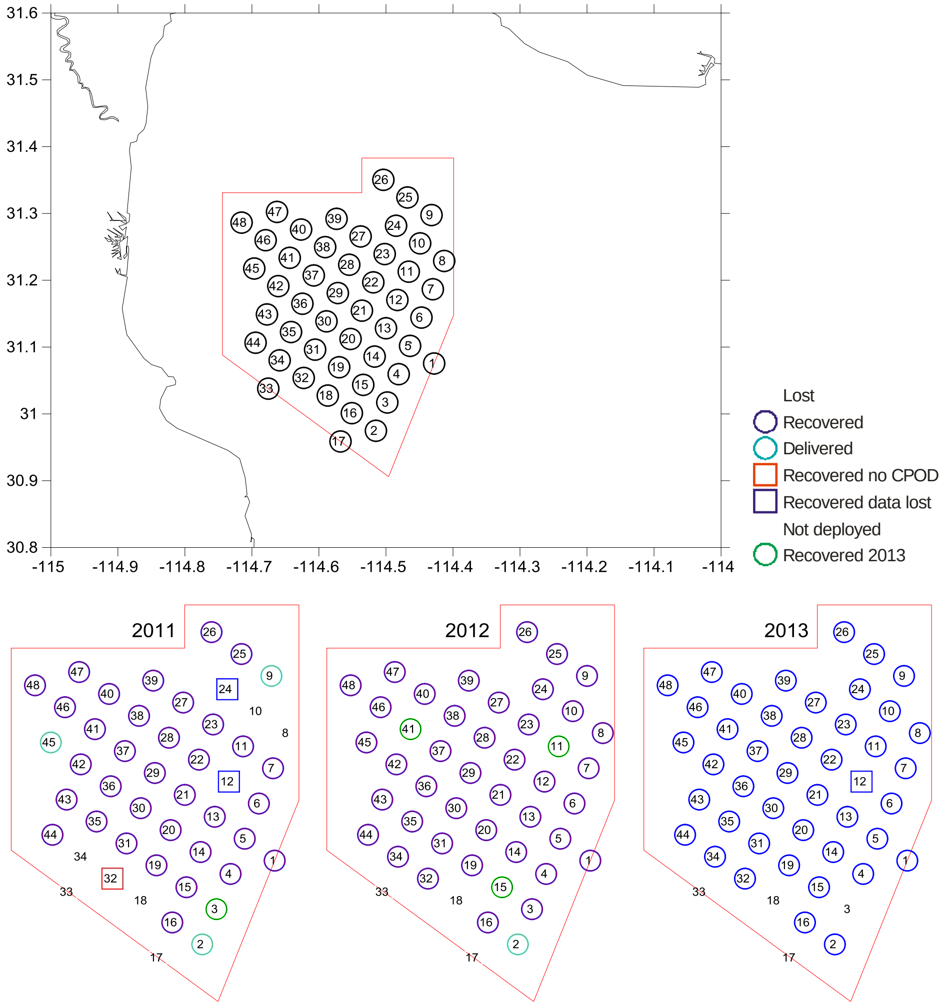


Figure 4. Position of the sampling sites inside Vaquita Protection Refuge (upper map, numbered circles). Below are the results of moorings and acoustic detectors recovery on the three past sampling seasons. Sites not enclosed by any symbol are places where no moorings were found or sites where no moorings were deployed, Circles indicate places where data is available and squares sites where moorings were recovered without detector or detectors recovered without data.

3. CPOD performance

Inside the Protection Refuge for Vaquita have been deployed a total of 141 moorings and acoustic detectors. 128 of them have been recovered by means of the planned routine or delivered back by other persons. This represents a recovery rate of 90.78%.

CPODs store data in a 4GB SD card, into 4 files near 1GB the first three and a fourth smaller due to the presence of the settings file. The files are populated in order from 0 to 3 as data is gathered. Along the three years of sampling already completed only on 27 times had been necessary to use the fourth file (Table I). When this has happened, on 22 occasions (81%) this file has been damaged. In few occasions reformatting of the card with the dedicated program has resulted in few days of additional data. The fourth file has been necessary mainly on sampling sites at the northern portion of the Protection Refuge, where waters are shallower and noisier.

On other occasions the CPODs have recorded few days of data. As the equipment is deployed by three months at least, it is considered that gather less than 60 effective days is low. Gather less than 50 days is too low. In total less than 60 days of data have been gathered on 23 times, 10 of them at a very low level, including a case of gather only five days (Table I) noting that the angle never changed its turned off angle position. Only on six of these occasions have coincided with a damaged fourth file (Table I), all at a low level. All the very low days of data cases occurred during 2013. Again, these events tend to occur on shallow and noisy areas, except for the very low data cases that occurred in 2013. The cause of this must be investigated.

In total occurred 44 events of abnormal data gathering, which represents 34% of the total sampling inside Protection Refuge along the three years. A matter of concern is raised at noisy areas as well as the very low volumes of data gathered at some sites during 2013. It must be discussed during the second meeting of the Steering Committee.

4. Row data analysis

Specialized CPOD program provided by the manufacturer of the equipment (Chelonia Limited) was used to identify Vaquita like click series. Every CP1 file is analyzed with KERNO classifier, which identifies series with narrow band high frequency (NBHF) clicks, potentially emitted by vaquitas, as well as wide band signals potentially emitted by other cetaceans like dolphins, sonars or other sources. This process creates CP3 files, which only contain information of the identified series, which greatly reduces the volume of data to be reviewed by the analysts.

Two analysts review all CP3 files to decide if the series identified as NBHF by KERNO classifier belong to vaquitas. A number of criteria are defined and recommended by the manufacturer, including click frequency and level, click duration (cycles), click band width, inter click interval and series envelope form. Analysts do not insert new series from inspection of data, but delete the ones not appearing as being emitted by vaquitas. At the end of the review use the export option to create text files containing 1 minute slices with ones if confirmed vaquita series were identified or zero if not. The minutes containing vaquita series are called Detection Positive Minutes (DPM).

Table I. Sites and PODs with events resulting in loss of data. The events are separated by year of sampling. D3 OK means that the fourth data file was written without error. D3 X means the fourth file had an error. Broken means that this POD was returned by a fisherman open and with the electronics board detached. Low means less than 60 days of data gathered but more than 50. For very low level actual number of day are shown. No angle change means that not a single click was stored as the angle of inclination of the POD never changed or the sensor was malfunctioning.

	2011			2012			2013		
Site	**POD**	**Event**	**Days**	**POD**	**Event**	**Days**	**POD**	**Event**	**Days**
2	998	Broken	Low						
6				1341	D3 OK				
8							1336		21
12							1342	No angle change	5
19							1302		12
20							2041		31
21							1301		37
22							1347		Low
26	995	D3 OK		1506	D3 X		2048	D3 X	
27				1501	D3 X	Low			
28	1009	D3 OK		1315	D3 X				
30				1349	D3 X	Low			
31							1338		44
34							1348		13
35							1315		Low
36	1350	D3 X	Low	1316	D3 X		1332		46
37	1342		Low				1316		47
38	1341	D3 X					1337	D3 X	
39	992	D3 OK		1505	D3 X	Low	1331	D3 X	
40	1348	D3 X					2047	D3 X	
41	1349	D3 X					1320		34
42	1343	D3 X	Low	1333	D3 X		1349	D3 X	
44							2040	D3 X	
45	1345		Low	1314	D3 X		1341	D3 OK	
46	1346	D3 X	Low	1309	D3 X		1333		Low
48				1343	D3 X		1311		Low

After the analysis of the first two sampling seasons data (2011-2012) it was noted that the "mechanics" of data displaying in CPOD program is complicated, needing to be changing displays with keystrokes constantly. To reduce this load on the analysts, and try to reduce time and facilitate analysis, a program was created using Visual Studio Express (Microsoft). This program uses the same CP1 and CP3 files to display data using a different "paradigm" (Figure 5). In one screen are presented all the acoustic parameters and click series are identified with color and number codes. Red dotes are displayed when parameter have NBHF like values. The routine to manage series is improved and a text box presents information including the separation in time between series. Comments can be added which are sent to a csv file including a time tag. Log files are created in order to have complete control of the analysis process.

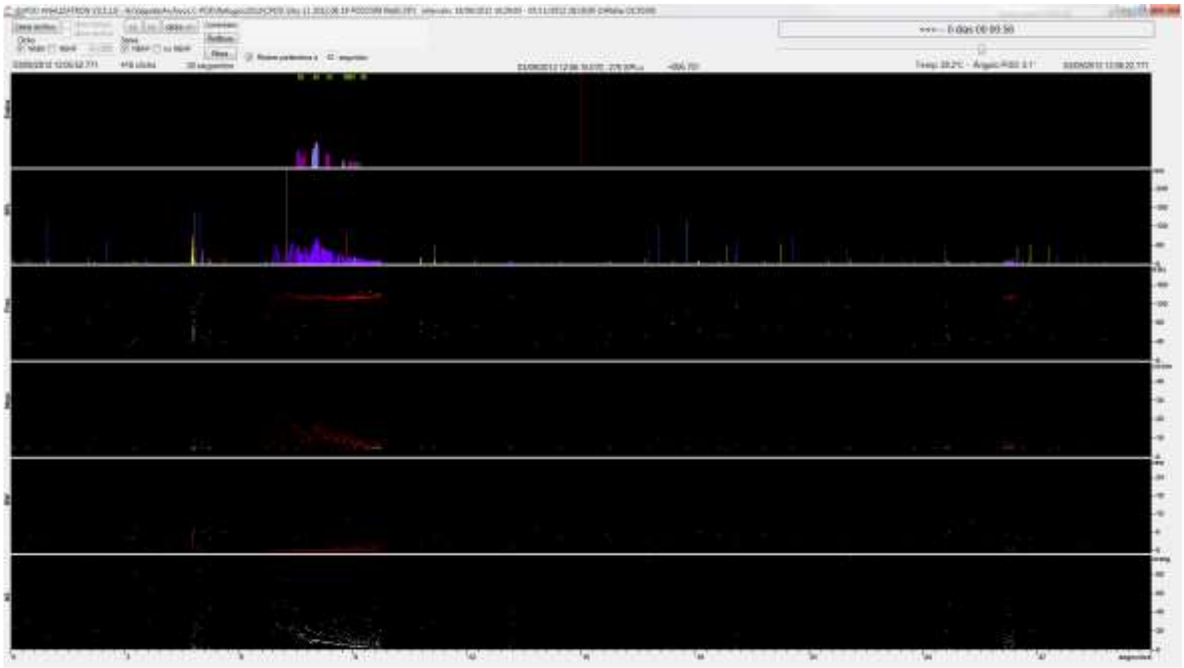


Figure 5. Display of the alternative program written to display CPOD data using a different "paradigm". Top panel shows the contents of the CP3 file, identifying click series and their quality with numbers and colors. Second panel shows the contents of CP1 file. Next panels show, respectively, the click parameters frequency, duration, band width and the inter-click interval. Information area on the top shows controls, general information and the time to the previous series displayed. A box is available to capture comments in a log file.

5. Data 2011 - 2013

A program was written using Visual Studio Express to manage the csv files created by CPOD. This routine identifies the acoustic encounters according to the criterion explained above and creates csv files with the total number of DPMs and encounters per site and day, which is the sampling unit (site-day). After using the alternative analyzing program the CP3 files are read directly to create the csv files with the results.

After three sampling seasons a total of 127 sites have been analyzed, including 9,817 whole days and 6,270 acoustic encounters of vaquitas. An acoustic encounter is defined as all the identified clicks series separated consecutively by no more than 30 minutes. The next table shows data per year:

	2011	**2012**	**2013**	***Total***
Sites	39	45	43	*127*
Days	3,019	3,785	3,013	*9,817*
Encounters	2,151	2,374	1,745	*6,270*

Figure 6 presents these data graphically. The horizontal axis is time and number of encounters per site per day in the vertical one. Every blue point represents the number of encounters in the station-day, in the date when this occurred. The cyan bars represent the distribution of encounter rate (encounters/site/day) per year. It is clear that the sampling units with zero encounters are extremely frequent.

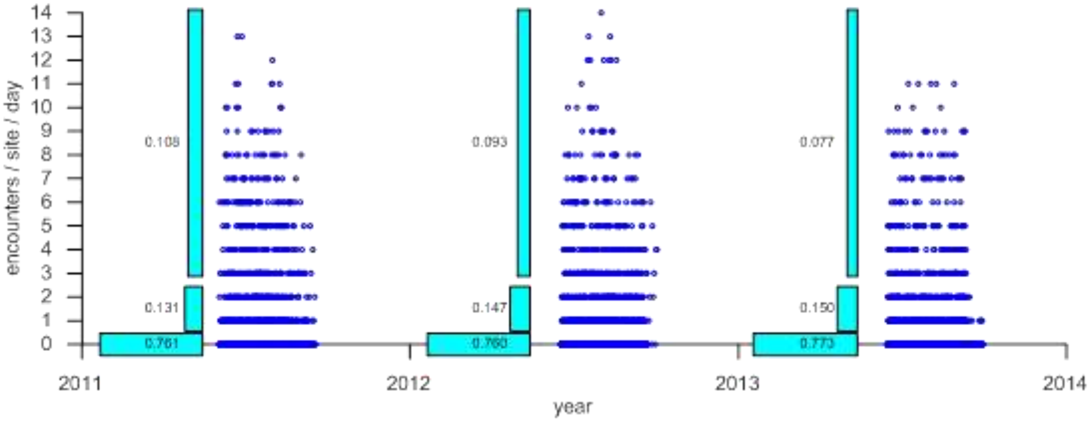


Figure 6. Scatter plot displaying all the data available for analysis. Blue points are individual site days at the date when they occurred. Cyan bars show the proportion of site-days with zero encounters, 1-2 encounters and 3 or more encounters, departing from a Poisson pattern.

6. An approximation to model encounter rate trend

The ratio of the variance over average encounter rate for 2011, 2012 and 2013 data, respectively, is 4.15, 3.94 and 3.82, which clearly departs from a Poisson distribution. Data is then over dispersed or zero inflated as compared with this distribution. Taken this into account, the model approximation used here was made supposing encounter rate data is distributed according to a negative binomial distribution, parameterized as (Ver Hoef and Boveng, 2007; Lord and Park, 2008; Lindén and Mäntyniemi, 2011;):

$$\boldsymbol{f(y;\lambda,r)=\frac{\Gamma(y+r)}{\Gamma(y+1)\Gamma(r)}\left(\frac{r}{\lambda+r}\right)^{r}\left(\frac{\lambda}{\lambda+r}\right)^{y}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 1}$$

where y is the value for which calculate the negative binomial probability, λ is the average and r is the dispersion parameter.

The simplest function to model the relationship between encounter rate and time could be, given that the domain of the encounter rate is in the positive numbers is:

$$\boldsymbol{y_t=e^{a+bt}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 2}$$

where y_t is the encounter rate at time t, and a and b are parameters to be estimated. Then, the parameter b determines the change of the encounter rate as the time progress. Negative values of this parameter mean a decreasing rate of the encounter rate, which is an indication of a negative trend of the population, given that no distribution shifts or acoustic behavior changes occur in the same period.

However, this simple model supposes that no other factors affect the encounter rate as measured in the sampling process described in this report.

The acoustic encounter rate is not homogeneously distributed along the Protection Refuge (Figure 7). The northern portion shows the lowest acoustic activity of vaquitas, while the southwest portion has the highest encounter rates. It appears that vaquitas tend to echolocate more frequently around sites 14 and 32, as indicated by the average distribution of the three sampling seasons combined (Figure 7).

The simple model described in Equation 2 could overcome this issue by using a balanced sampling, including data only for days when all sampling stations have data. It occurs because acoustic detectors are not deployed all in the same day, and every one turns off on different days depending on battery duration and data volume gathered. This approach would result in discarding valuable data; hence a better approach is to use a model including the variability due to distribution of encounter rate. On the other hand, it is known that the Upper Gulf of California basin is characterized by a very extreme tidal range, which could result in differential encounter rates between neap and spring tides. A model including all these variables could be used to better understand the encounter rate trend with time:

$$\bar{y} = e^{b_0+(b_y y)+(b_{lat} lat)+(b_{lon} lon)+(b_t t)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3}$$

Where $\bar{y}$ is the average acoustic encounter rate given the variables in the model, ***y*** is the sampling year (considering the change of acoustic detection rate is negligible during the three months of sampling season), ***lat*** and ***lon*** are the latitude and longitude of the sampling sites, ***t*** is the tide expressed as the difference between the upper and lower tide level of the sampling day, b_0 is the intercept parameter of the model and b_y, b_{lat}, b_{lon}, b_t are the parameters (coefficients) determining the relationship between the variables in the model and the acoustic encounter rate.

The relationship between encounter rate with year and tide could be intuitively linear; however the spatial structure seen in Figure 7 is more complicated and could be better modeled with a polynomial. Hence it was essayed the fitting of second and third degree polynomials on latitude and longitude:

$$\bar{y} = e^{b_0+(b_y y)+(b_{lat} lat)+(b_{lat2} lat^2)+(b_{lat3} lat^3)+(b_{lon} lon)+(b_{lon2} lon^2)+(b_{lon3} lon^3)+(b_t t)} \quad \ldots\ldots \text{Equation 4}$$

Where b_{lat2} and b_{lon2} are the parameters added to the model with second degree polynomials for squared latitude and longitude. Parameters b_{lat3} and b_{lon3} are the case for third degree. The second degree model is the Equation 4 not including the cubic terms.

A Bayesian approach was used to estimate the parameters of the models (Gelman *et al*., 1995; Kruschke, 2011) using non-informative uniform priors for parameters centered at a value of zero. AD Model Builder (ADMB; Fournier *et al*., 2012) was used to estimate posterior distributions using the Monte Carlo Markov Chain (MCMC) routine as implemented in ADMB using the Metropolis-Hastings algorithm (Chib and Greenberg, 1995). Likelihood portion of the joint posterior distribution was based on negative binomial distribution as in Equation 1, considering the dispersion parameter ***r*** as and hyper-parameter to be estimated, using a semi-informative uniform prior bounded between 0.01 and 5.00.

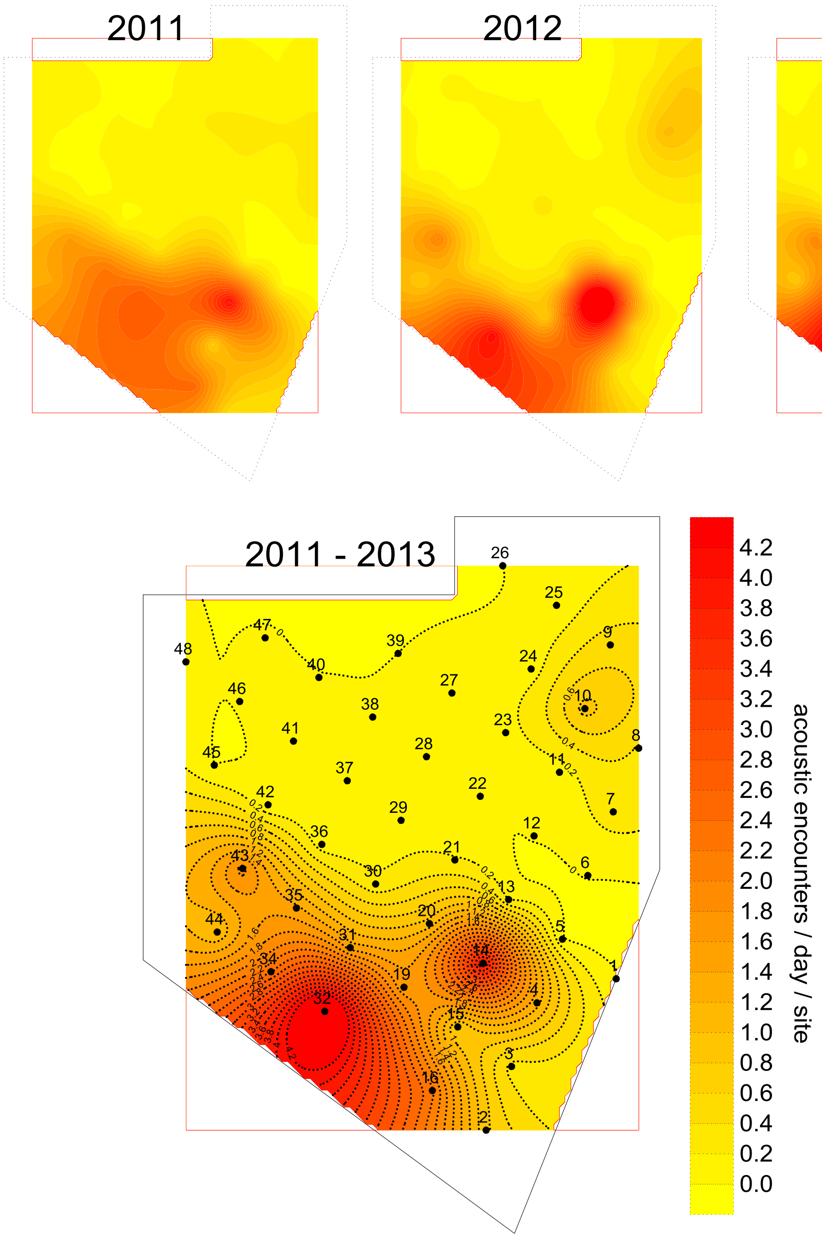


Figure 7. Acoustic encounter rate contour maps based on data for every sampling year and all data combined. The map for all data shows the position of the sampling sites. It is evident the heterogeneous distribution of the encounter rate and the highest acoustic activity around sites 14 and 32.

The optimization phase of ADMB (maximum likelihood estimation) was used to verify that models were numerically stable and correctly specified. Then the MCMC was run using zero as starting values for parameters except for dispersion parameter $\boldsymbol{r}$, which was started at a value of 0.2.

All models (equations 2, 3 and the polynomials in equation 4) were fitted using 500,000 MCMC simulations. Data for the simple model in Equation 2 only include days when all stations for the corresponding year have data, totaling 5,554 site-days.

Table below shows a description of the posterior distributions of parameter $\boldsymbol{b}$ for simple model and $\boldsymbol{b}_y$ for lineal and polynomial models. Figure 8 shows histograms of the same posteriors. For all models 95% credible intervals do not contain positive values for these parameters and the probability of a value lower than zero is greater than 0.99, indicating that a positive trend of encounter rate with time is unlikely.

Model	Min	Max	Average	Median	Std dev	Equal Tail Interval		Highest Density Interval		Credibility value <0
Simple	-0.3834	0.0334	-0.1771	-0.1770	0.0484	-0.2723	-0.0825	-0.2706	-0.0810	0.9999
Lineal	-0.2147	0.0465	-0.0851	-0.0851	0.0308	-0.1455	-0.0246	-0.1449	-0.0242	0.9971
Second degree	-0.2206	0.0491	-0.0903	-0.0903	0.0313	-0.1521	-0.0289	-0.1521	-0.0290	0.9980
Third degree	-0.2440	0.0295	-0.0932	-0.0930	0.0310	-0.1540	-0.0322	-0.1542	-0.0325	0.9988

The simple model estimates that average encounter rate in the Protection Refuge changed from around 0.76 encounters/day/site in 2011 to 0.53 in 2013, approximately a 16% annual decreasing.

Fixing latitude and longitude at the position of site 14, and tide difference at 2 meters, lineal, second degree and third degree models estimate negative annual changes of the average encounter rate of around 8.16, 8.64 and 8.90% respectively.

It is known that vaquita population decreased at an approximate annual rate of 7.6% between 1997 and 2008 (Gerrodette *et al*., 2011). On the other hand, acoustic encounter rate decreased at an annual rate of approximately 8.34% (Jaramillo Legorreta, 2008), meaning that acoustic encounter rate could vary in direct proportion with abundance. Taking into account that since 2008 the Mexican Government initiated a program to reduce fishing effort that kills vaquitas, the adjustment of the simple model is unlikely as compared with the models including variation due to geographical position and tide in the sampling site.

Figure 9 shows output of the models as contours of encounter rate fixing the tide difference at 2 meters and year 2013. Comparing with data under these conditions, the third degree model appears to explain better the spatial variation of the encounter rate, although not locating precisely the sites with higher acoustic activity.

In conclusion, the modelling exercise after three sampling periods appear to have a high credibility that the acoustic encounter rate has been decreasing since 2011 at a rate higher than 8% per year, indicating the same fate for vaquita population level.

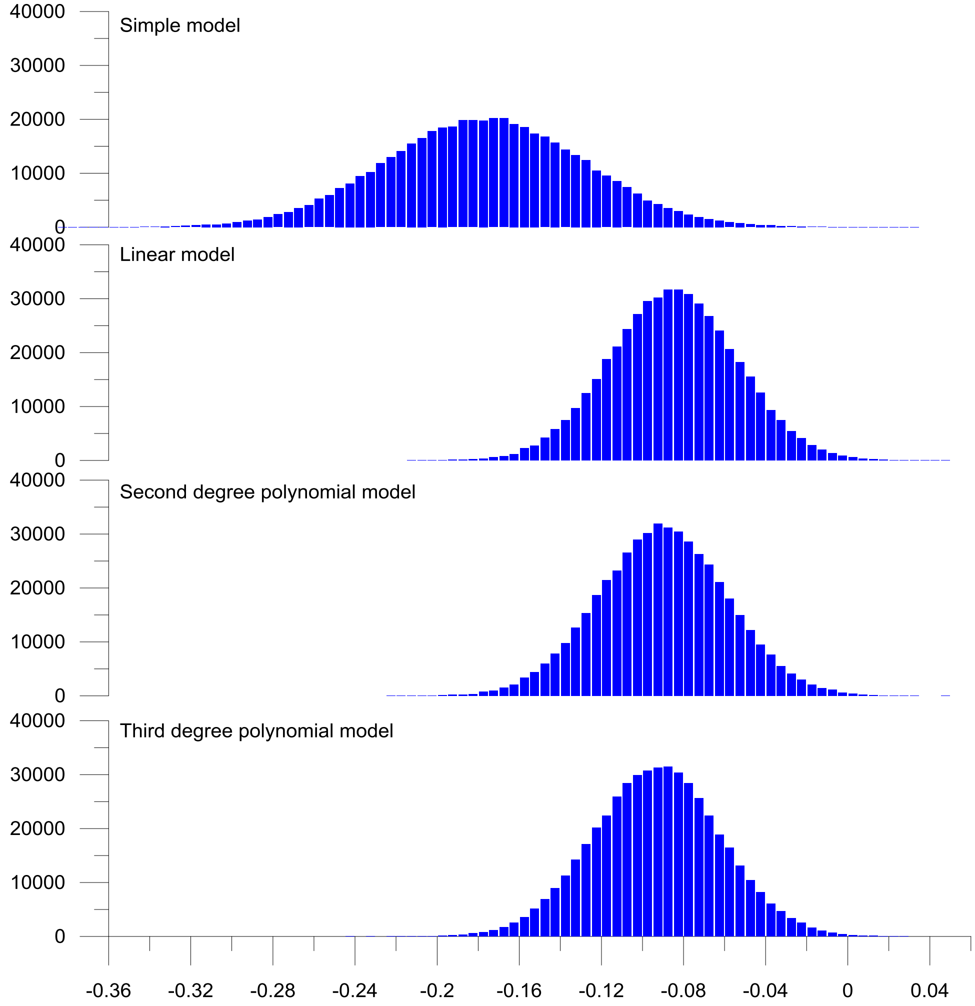
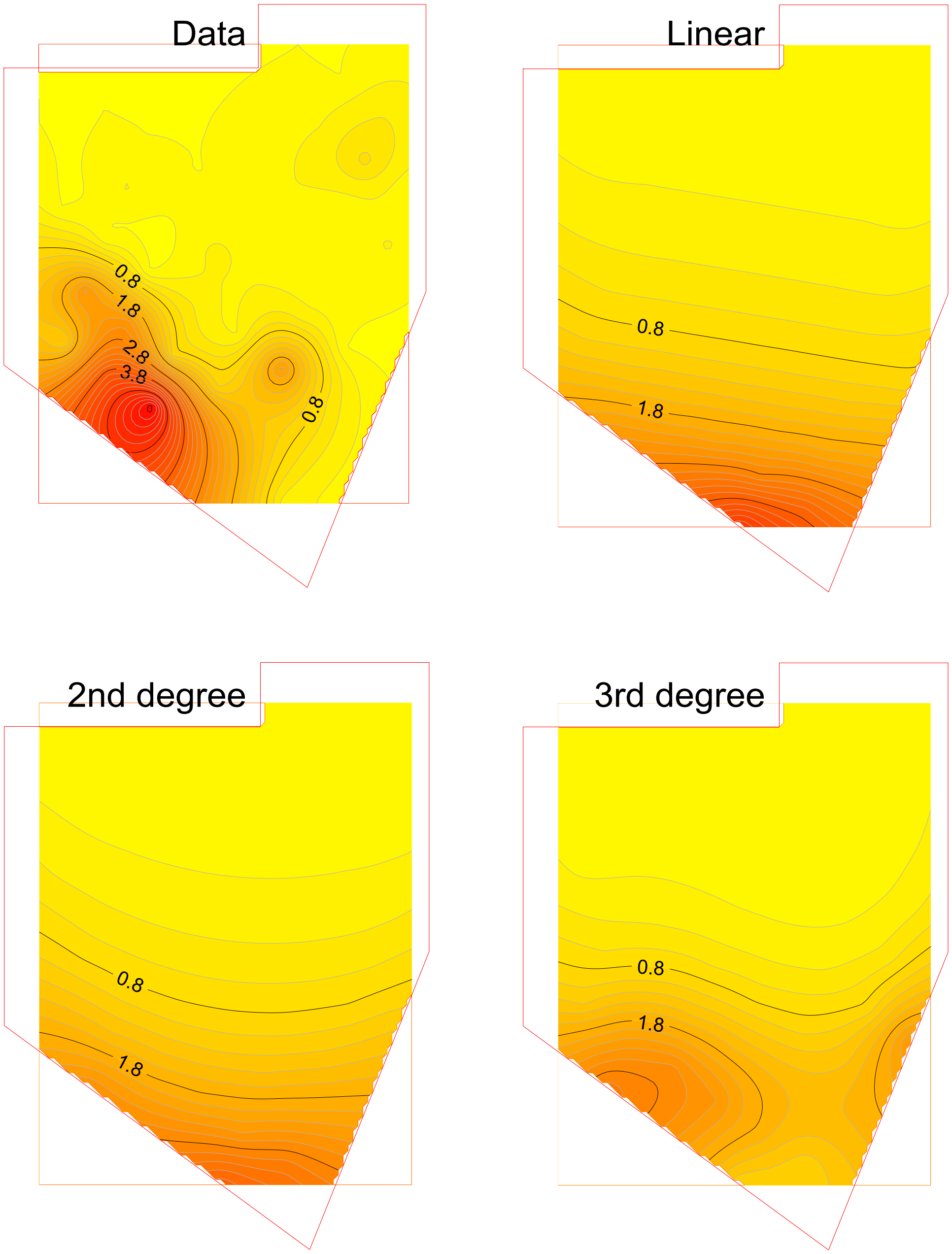


Figure 8. Posterior distributions of parameters ***b*** (top histogram) and $\boldsymbol{b_y}$ for the four models fitted. It is noted that simple model results in a more dispersed distribution. The other distributions are very alike, varying slightly in its mode.



Data

Linear

2nd degree

3rd degree

Figure 9. Acoustic encounter rate contour maps based on output of the models with space variation. It is evident that third degree model is the one better representing the map based on data. The output of models is obtained fixing for year 2013 and tide range 2 meters.

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Second Meeting of the Steering Committee of the Vaquita Acoustic Monitoring Program
April24-25, 2014
Chair: Armando Jaramillo
Attendance: Lorenzo Rojas Bracho, Gustavo Cardenas Hinojosa, Edwyna Nieto Garcia,
Francisco Valverde Esparza, Martin Sao,
Nick Tregenza, Tim Gerrodette, Barbara Taylor,
Jay Barlow, Tim Ragen, Annette Henry,
Eiren Jacobson

Executive Summary

Mid-project results of the vaquita acoustic monitoring project indicate a critical decline in vaquita numbers since 2011. Raw data indicate declines of 7.5% and 14.9% in average Detection Positive Minutes (an index of vaquita presence) from 2011 to 2012 and from 2012 to 2013, respectively (Figure 1). Preliminary analyses indicate that the decline in vaquita abundance is likely to be even greater. Small populations are vulnerable to cumulative, interacting risks, like inbreeding depression and increased variability in population growth rates, that can accelerate their decline to extinction. As the vaquita population declines, it may reach a point of no return from which recovery is not possible. We do not know what that point is for the vaquita. Based on concerns about inbreeding depression, Jaramillo et al. (2007) chose 50 adults, a number identified by Franklin (1980) necessary to retain reproductive fitness. Adults likely comprise about half of the current vaquita population, so the threshold of total abundance (all ages) would be about 100. During the 65a Scientific Committee meeting, CIRVA members produced an analysis, required by the Government of Mexico, which used a Bayesian model to estimate the 2013 abundance of the vaquita population. The posterior distribution for that year´s abundance indicated a best estimate of 189 individuals.

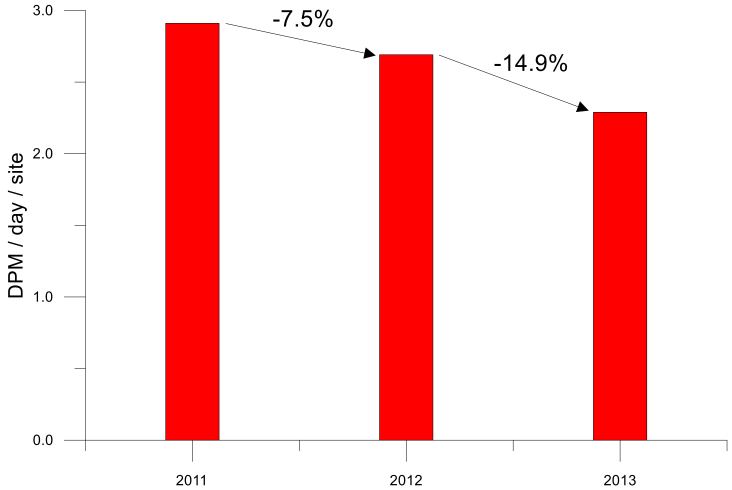

Figure 1. Average Detection Positive Minutes (DPM) per day with the percent decline between years.

The Steering Committee (Committee) found that deployment and retrieval of acoustic monitoring devices (C-PODs) inside the Vaquita Refuge had been very successful in the first 3 years of the 6-year project; the scientists conducting the study retrieved more than 90% of deployed C-PODs. The C-PODs performed well and collected data that would have been sufficient to detect the hoped-for 4%/year increase over a 5-year interval (6 survey periods), had such an increase occurred. Two scientists processed the data independently and they compared their results with those of a computer program designed to detect porpoise vocalizations. The comparison produced nearly perfect agreement. The Committee agreed that the data were of high quality and that the performance of the entire team carrying out this project was exceptional.

The Committee examined summary statistics for the raw data and the results of detailed analyses to estimate the rate of change in vaquita abundance. All approaches indicate that vaquita population is declining and the rate of decline appears to be as great or greater than any decline ever recorded for the population. Given their critically low abundance, all plausible scenarios indicate that without effective remedial action the species could become extinct in the near future.

The Committee discussed factors that may confound interpretation of the data. Notably, the highest detection rates were from the southernmost C-PODs, which could indicate that vaquitas moved southward out of the monitoring area. However, past surveys have shown vaquita distribution to be remarkably consistent over a long time period (Figure 2). Those visual data indicate an area of longstanding low density next to the southwest boundary of the Refuge. Currently, monitoring data for the area are not available because all C-PODs placed there (on or just outside the Refuge's southwest boundary) were lost. To confirm that vaquita are not using the area around the southwest boundary of the Refuge, the Committee recommended adding 5 C-PODs just inside that boundary. The Committee also recommended increasing enforcement along the boundary during the monitoring season and replacing C-PODs frequently during the season to ensure quick recovery of the collected data.

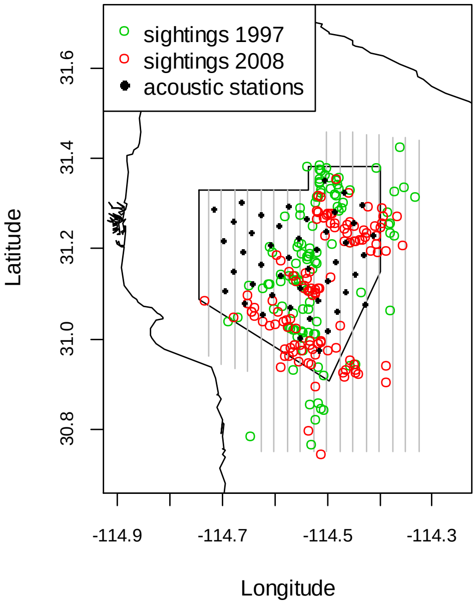

Figure 2. Visual detections (red and green circles) from the two major ship surveys with the ship track lines shown as light gray lines. The C-POD locations are shown as black dots and the Vaquita Refuge is outlined in black.

The Committee agreed that the estimated annual rates of decline from 2011 to 2013 are so severe and the vaquita's status so serious that immediate action is essential to save this species. Nonetheless, to confirm its findings, the Committee is planning an immediate review of its data, analyses, and preliminary findings. The Committee is seeking the necessary funds and has identified a small group of experts well suited to provide the review.

Full Report

The Committee of the acoustic monitoring program for vaquita held its second meeting on April 24-25 in Ensenada, Mexico. The objectives of the meeting were to review and evaluate the technical aspects of the passive acoustic monitoring project and to consider results mid-way through the project to determine if the monitoring program should be adjusted. The acoustic monitoring devices are called C-PODs. Technical aspects include –

- the mooring of C-PODs within, on the delimiting buoys, and outside the Vaquita Refuge (hereafter referred to as the refuge)
- the performance of the C-PODs, and
- the interpretation of the C-POD data.

The Committee also considered how to communicate results to authorities and other interested non-scientist parties including the communities near vaquita habitat.

C-POD Bottom Mooring

Deployment and retrieval of C-PODs within the refuge has been very successful with a retention rate of more 90% (Figure 3). Equipment retrieval takes on average 15-20 minutes. If retrieval was unsuccessful with a single panga, most C-PODs were retrieved when three pangas were used. Details of deployment and recovery are given in the Progress Report (Appendix 1). The Committee recommended that the methods developed by the Mexican crew to moor and retrieve C-PODs using light-weight, inexpensive materials should be published as a technical note so that others could benefit from their success.

C-POD Perimeter Buoy Mooring

The monitoring program was devised to collect year-round data from a set of perimeter buoys (which mark the boundaries of the Vaquita Refuge) to characterize potential seasonal or annual shifts in vaquita distribution. The expectation was that fishermen would avoid entangling their gear in the buoys, which would make them good mounts for the C-PODs if the C-PODs were not visible from the surface. The investigators used a series of buoy-C-POD configurations (details in Appendix 1). Unfortunately, nearly all C-PODs deployed with buoys were lost. Over the 3 years of the study perimeter buoys produced 971 C-POD-days of data. Had the perimeter buoys been successful there would have been approximately 13,000 C-POD-days of data. Whether the loss was intentional or accidental (i.e., by entanglement in fishing gear), it is clear that buoys cannot be used for attachment of C-PODs. The investigators are using dummy C-PODs to test new methods for anchoring C-PODs near or on the Refuge boundary.

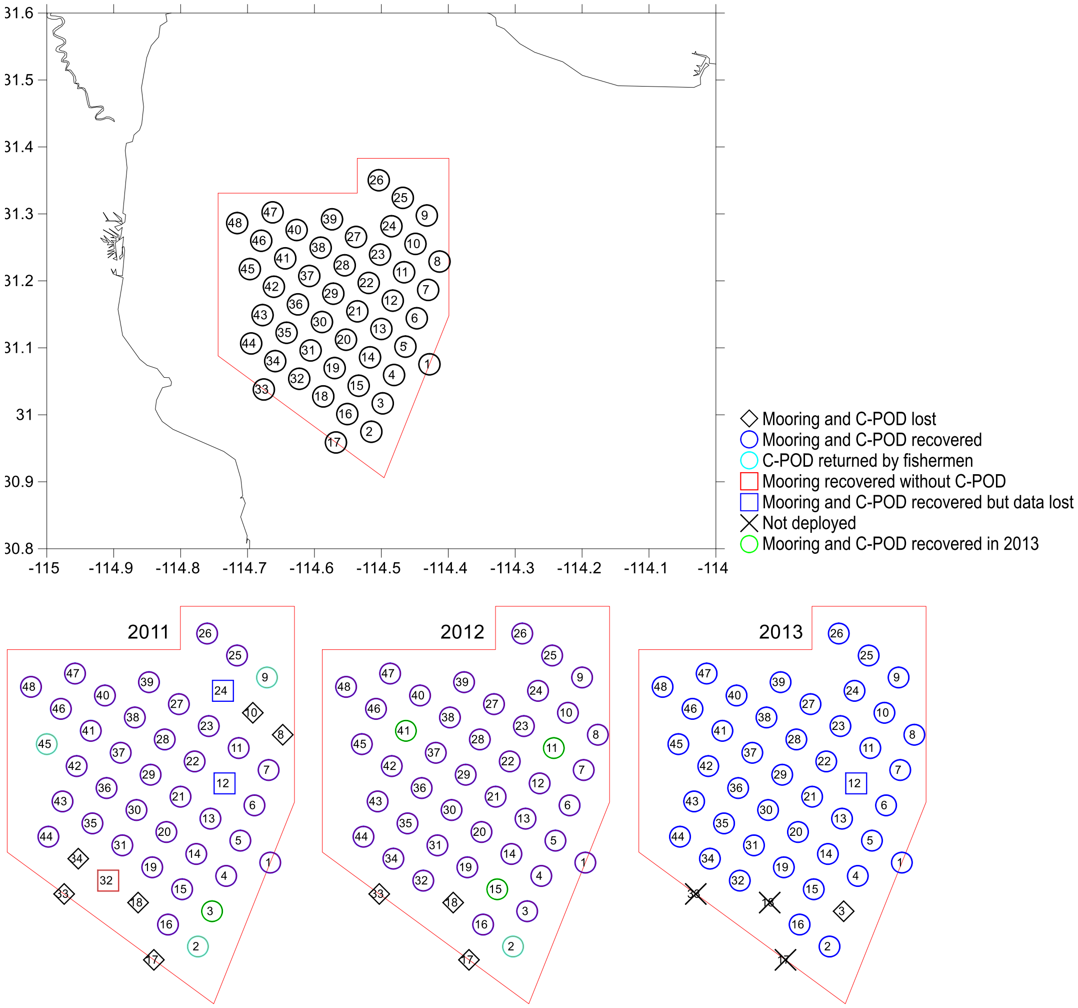

Figure 3. Position of the sampling sites inside the Vaquita Refuge (upper map, numbered circles). Below are the results of moorings and acoustic detectors deployed in 2011, 2012, and 2013. C-PODs were not deployed at sites 17, 18, and 33 in 2013 (X's). Circles indicate sites where data are available, diamonds indicate all equipment lost at that site, and squares indicate sites where the mooring was recovered without the detector or the detector was recovered without any data.

<u>*Loss of Moorings Used to Monitor Vaquita Outside Vaquita Refuge*</u>

The 2009 Acoustic Monitoring Workshop and CIRVA (2012) recommended study of vaquitas outside the Refuge. Barbara Taylor provided funding for a study to estimate the loss rate of acoustic stations for monitoring vaquitas outside the Refuge. The mooring design used outside the Refuge was the same as that used inside the Refuge.

Eight moorings with dummy C-PODS were deployed on 30 July 2013 outside the western edge of the Refuge (Figure 4). Recovery of C-PODS was attempted in September 2013 prior to shrimp season and the average recovery time was 50 minutes (range 18-61 minutes). Two (25%) of eight moorings were recovered, both from the area west of the Refuge. None of the C-PODs along the southwest refuge boundary were recovered. As noted above, this boundary is the area of greatest interest because C-PODs just inside this boundary have the highest vaquita detection rate, indicating that vaquita may move outside the Refuge in this area.

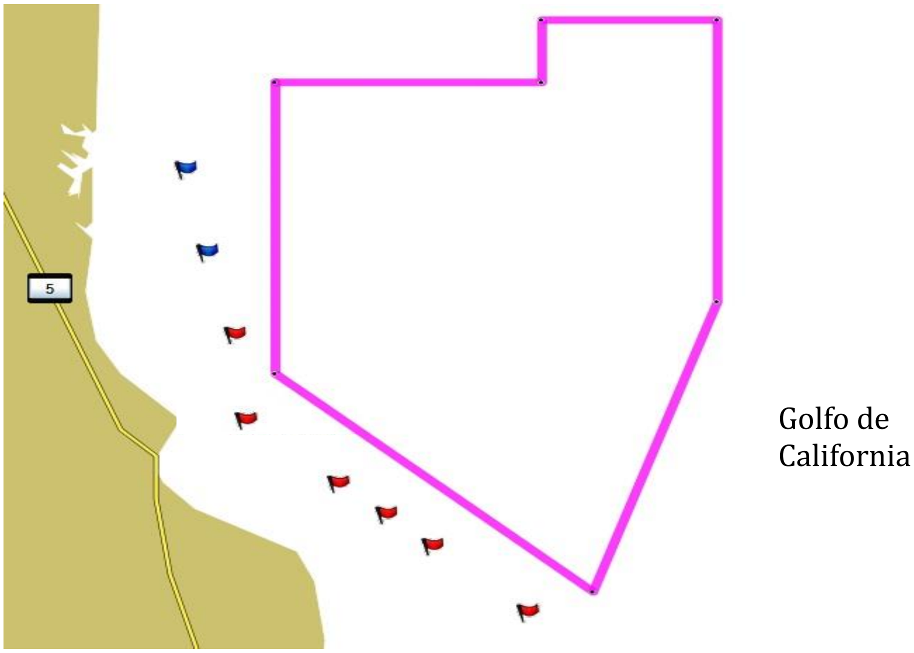

Figure 4. Positions of recovered (blue) and lost (red) moorings.

The high loss rate was not expected because the moorings were deployed during the period of lowest fishing effort. However, large commercial trawlers are used to catch fish during this period and in this area, and this part of the vaquita's range has no protection from any type of fishing. The Committee discussed methods to reduce the loss rate through the use of 3 recovery pangas, short-term deployments, or even guarding the C-PODs. Given the high loss rate, these alternatives seemed unlikely to yield sufficient data without great expenditure from guarding the C-PODs or deploying large numbers of them to compensate for the loss rate.

Monitoring the Refuge boundary and Outside Areas

The Refuge boundary and outside areas are not monitored and such monitoring does not appear to be feasible in the foreseeable future. The Committee discussed several alternatives. One suggestion was to use the *Koipai* (a boat capable of deploying acoustic monitoring devices) to conduct stationary sampling year round. Again, the purpose of such sampling would be to determine if changes in vaquita detection rates within the Refuge are due to shifts in distribution.

For the purpose of distinguishing a population decline from a shift in population distribution, the more important question is whether the population moves outside the Refuge in the summer months when the C-PODs are deployed. Past visual surveys conducted in fall months indicate the distribution of vaquita in fall months is consistent, which argues against a shift in distribution. If, as suspected, the vaquita do not shift their distribution, then the most likely explanation for a reduced number of acoustic detections within the refuge is a reduced number of vaquitas.

The Committee decided that a sailboat-towed array would not provide sufficient data to test the hypothesis of a distribution shift even if the boat operated day and night. Instead, the Committee recommended hiring fishermen to do daily C-POD deployments in the area south of the Refuge. The first year would be used to determine the amount of data necessary to test the hypothesis of movement of vaquitas outside the Refuge as a reason for the observed decline within the Refuge. That information would be used to plan future monitoring in this area.

C-POD Performance

Overall performance of C-PODs was good. Several programming problems limited the amount of data that could be stored by some C-PODs. However, those limitations do not appear to have compromised the data collected and the programming problems will be remedied before the next season. Further details are given in Appendix 1.

Preliminary Results

Figure 5 illustrates the level of acoustic monitoring effort (i.e., days of acoustic monitoring per C-POD station) for different years.

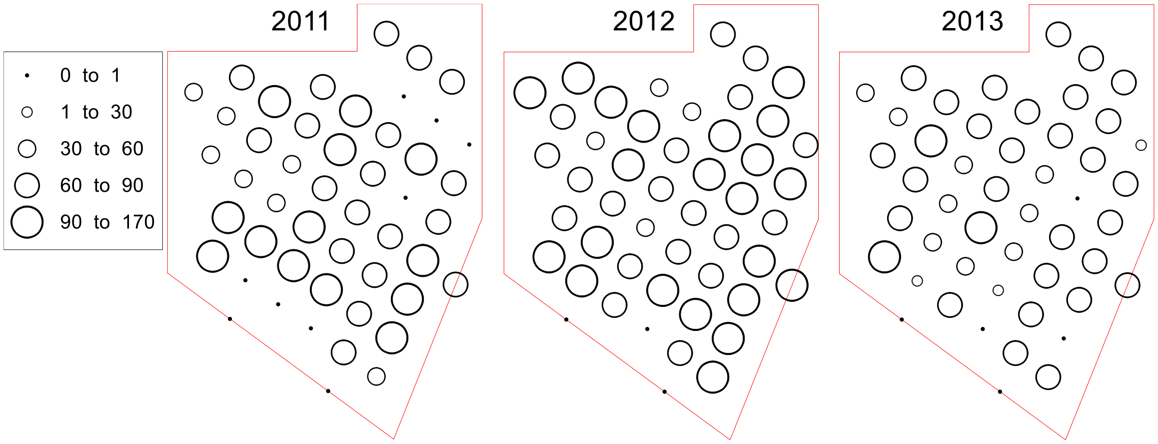

Figure 5. Number of days of monitoring effort for each sampling site indicated by circle size

Validation of Vaquita Signal Identification (GENENC)

A blind test was conducted to assess potential detection differences between two independent data analysts (E. Nieto and G. Cardenas) and a computer algorithm developed to identify porpoise acoustic signals (GENENC). GENENC is an encounter classifier and can be used as a validation reference tool. It is designed to minimize errors in classifying other noises as vaquita clicks (false positives). GENENC uses information from an encounter, which is defined as a sequence of trains with no gap longer than 2 min. It does not detect all porpoise encounters that could be identified by a skilled analyst, but the loss is relatively small and program performance should be stable over time, making it an easy-to-use reference tool. The analysts reviewing the data visually followed the same guidelines as used in the computer algorithm. Their results and those of GENENC were nearly identical in terms of the numbers of detection positive minutes (DPM/day correlations: 2011: 0.974; 2012: 0.976; 2013: 0.974). Of the 1528 DPMs recorded, 1521 were considered to be true detections of vaquita and 7 (0.4%) were considered false positives caused by detection of dolphins. Details for these analyses and the GENENC and visual classification comparison are given in Appendix 2.

Although the Committee considered the difference between the analysts' results and computer results to be negligible, it also suggested that the error rates of the two analysts should be compared and presented. Quantifying the error rate between the two analysts could be accomplished using Mark-Recapture methods with the same dataset.

Jaramillo developed an "all on one screen" display to facilitate data analysis. This program uses the same CP1 raw data and CP3 processed data files created by CPOD program, visually displays needed information, and reduces analysis time. The Committee commended Jaramillo for developing such a useful tool and recommended it be made available to others.

Choice of Metrics: Clicks per Day (Clicks/day), Encounters per Day (Enc/day), or Detection Positive Minutes per Day (DPM/day)

The Committee discussed which units of acoustic activity should be used in the analysis. 'Encounters' are periods of detected activity defined by some silent gap at each end. (These data have been analysed using a 30-minute gap). However, most acoustic researchers have moved away from counting encounters to either counting clicks or DPMs. Each metric has some advantages and some disadvantages.

Counts of clicks per day may conflate behaviour with presence, as animals click more rapidly during prey capture and more slowly while travelling. In the data collected to date the difference between mean click rates in successive years is low. (Mean click rates per second within identified click trains in 2011, 2012 and 2013 were 86.9, 90.8 and 92.8, respectively).

Click counts have the advantage that they will reflect group size reasonably if animals in a group generally continue clicking. This is because the sound beam produced by the animal is very narrow and is recorded only briefly as it sweeps across the hydrophone, and the recording only becomes saturated at very high animal densities.

The sum of train durations is the measure of duration of detectability that is most resistant to saturation. In this data set it correlates tightly with click counts (linear regression over 3 years $R^2 = 0.98$). It has not (yet) been widely used, but may be expected to avoid conflating behaviour with density, and to reflect group size.

DPM also is not much affected by behaviour but can saturate during periods of high local density. It is widely used and understood in acoustic monitoring of echo-locating cetaceans. In this data set DPM and click counts correlate closely (Figure 6).

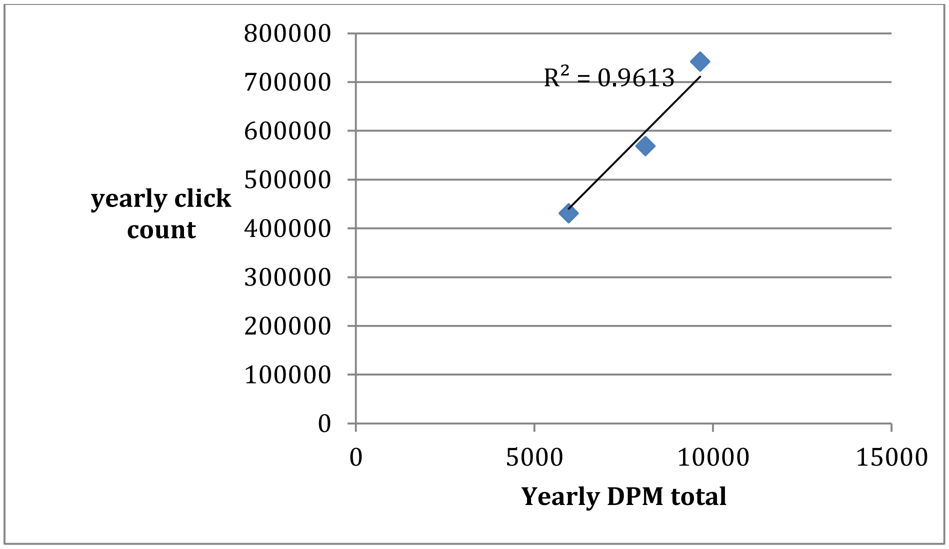

Figure 6. Relationship between the yearly click count and the yearly total DPM).

The SAMBAH project is assessing the greatly depleted harbor porpoise population of the Baltic Sea. That project is using detection positive seconds, which is a more appropriate measure for estimating absolute abundance using a distance-detection function that is being developed for that project.

Porpoise positive days, PPD, has been used to present and communicate information collected with PODs in the German Baltic. This measure is easy to understand, but it saturates at densities well below those seen in this study at the sampling sites with the highest detection rates. It would measure the spread of the population rather than its size.

Encounters are the longest of the plausible measures and may be confounded because a long period is allowed between vocalizations. The total number of encounters also may not reflect group size and is affected strongly by animal movement speeds. For example, an increase might arise from the presence of dolphins or shifts in prey size or type (benthic to pelagic etc.) and this would tend to generate more, shorter, encounters from the same density of animals. If encounters are long, a reduction in logger sensitivity could increase encounter numbers by splitting them, a perverse effect, and encounter rates saturate locally if animal movement rates are low.

Visual surveys have shown that vaquita group size has remained constant over time, which indicates that the encounter-rate metric is less likely to be biased. Analysis of the acoustic monitoring data from 2011 to 2013 using encounters indicates that detection rates are declining in a manner that is broadly consistent with analytical results based on other measures. In this case, encounter rates also can be more easily compared to the findings of Jaramillo when he used different equipment and demonstrated the serious progressive decline in detection rates that – based on the 2011 to 2013 data – appears to be continuing. Assumptions are summarized in Table 1 with other considerations listed below.

Table 1. Assumptions required for use of different metrics to infer trends in vaquita numbers.

	Acoustic Units		
Assumes:	Encounters	DPM	Clicks/unit time
Constant distribution of vaquitas over time	Y	Y	Y
Constant vaquita movement rates	Y	N	N
Constant click rates over time	N	N	Y
Constant group size	Y	Y	N

Other considerations:

<u>In addition, the metric "encounters per day" –</u>

- will saturate in high densities
- can be affected by noise (but less sensitive to saturation within a minute)
- is sensitive to definition of "encounter."
- cannot include time-of-day covariates in models.

Both DPM and clicks/unit time are affected by noise saturation (>4096 samples/minute). Finally, the DPM metric is robust to movement rate and click rate changes.

Vaquita behavior is not well understood and we do not know how it changes from year to year. Therefore, the Committee recommended that the analysts test the sensitivity of the analytical results to the metric used. The aim of the sensitivity analysis would be to compare results and, if they agree, then conclusions are robust to the metric. If results differ, further research will be needed.

<u>Effects of Dolphins on Vaquita Detections</u>

Dolphins may cause vaquitas to decrease vocalizations, move away, or both (Eiren Jacobsen pers. comm.). As part of his Ph.D. research, Gustavo Cardenas is using the C-POD data to investigate the potential influence of dolphins on vaquita vocalization. The Committee welcomed this research and looks forward to seeing the results. His methods were as follows:

- He used a panga to conduct six surveys in the Refuge between August 2013 and March 2014.
- His most common cetacean sightings were long-beaked common dolphins, followed by Bryde's whales, bottlenose dolphins, vaquitas, and humpback whales.
- During encounters with dolphins, he navigated the panga toward their swimming trajectory and deployed a buoy with acoustic detectors to record their vocalizations.
- During the surveys he also recorded noise produced by fishing boats and shrimp trawlers. He also recorded those boats with his panga engine turned off to provide more accurate recordings. In one location, he observed long-beaked common

dolphins feeding behind trawlers and bottlenose dolphin feeding on fishery discards. To get a better recording, he deployed a buoy with a recorder and then moved the panga 500 m from the buoy.

- He will analyze his acoustic recordings using the C-POD software.
- When he has characterized the vocalizations of the different species and the sound signatures of the recorded vessels, he will then use the data to determine whether the presence of dolphins or vessels affect the acoustic detection of vaquitas.

Effects of Noise on Detectability of Vaquitas

Very few vaquita were detected in the northwestern portion of the Refuge. The C-PODs in this area were saturated by noise from moving sediments and snapping shrimps. Jaramillo tested whether vaquita click trains might have been missed in this area because of noise masking by inserting a vaquita signal into a file from a noisy sampling location. GENERC was able to find that signal more than 80% of the time. These results gave the Committee confidence that vaquita densities are actually low in these high-noise areas.

Trends in Vaquita Abundance Inferred from Acoustic Detections

The acoustic monitoring project assumes that acoustic detections are proportional to the number of vaquitas: more vaquitas will make more detectable sounds. If acoustic monitoring effort were equal across the vaquita's range and the vaquitas did not change their behavior in some significant manner, then the raw number of detected vaquita sounds should change at the same rate as vaquita abundance. However, if the monitoring effort changes in different years, the interpretation of the data becomes more complex. The dataset examined here has just such complexities because C-PODs that were not recovered in 2011 were from locations with high detection levels in 2012 and 2013. Also, the amount of data from each C-POD is not equal (Figure 5). In this preliminary analysis, the raw results are given first followed by the results of several analytical models that account for differing effort across the Refuge and over time.

Spatial Results

Figure 7 shows smoothed levels of acoustic detections of vaquitas within the Refuge and for the different years. Blank areas in the 2011 map indicate areas where no acoustic data were collected (see effort data in Figure 5). The Committee noted that the areas of missing data in 2011 corresponded to areas of high acoustic detections in 2012 and 2013 (sample sites 10, 16, 32 and 34). Like the earlier visual data, these acoustic data also indicate that areas where vaquitas are detected remain relatively constant through time.

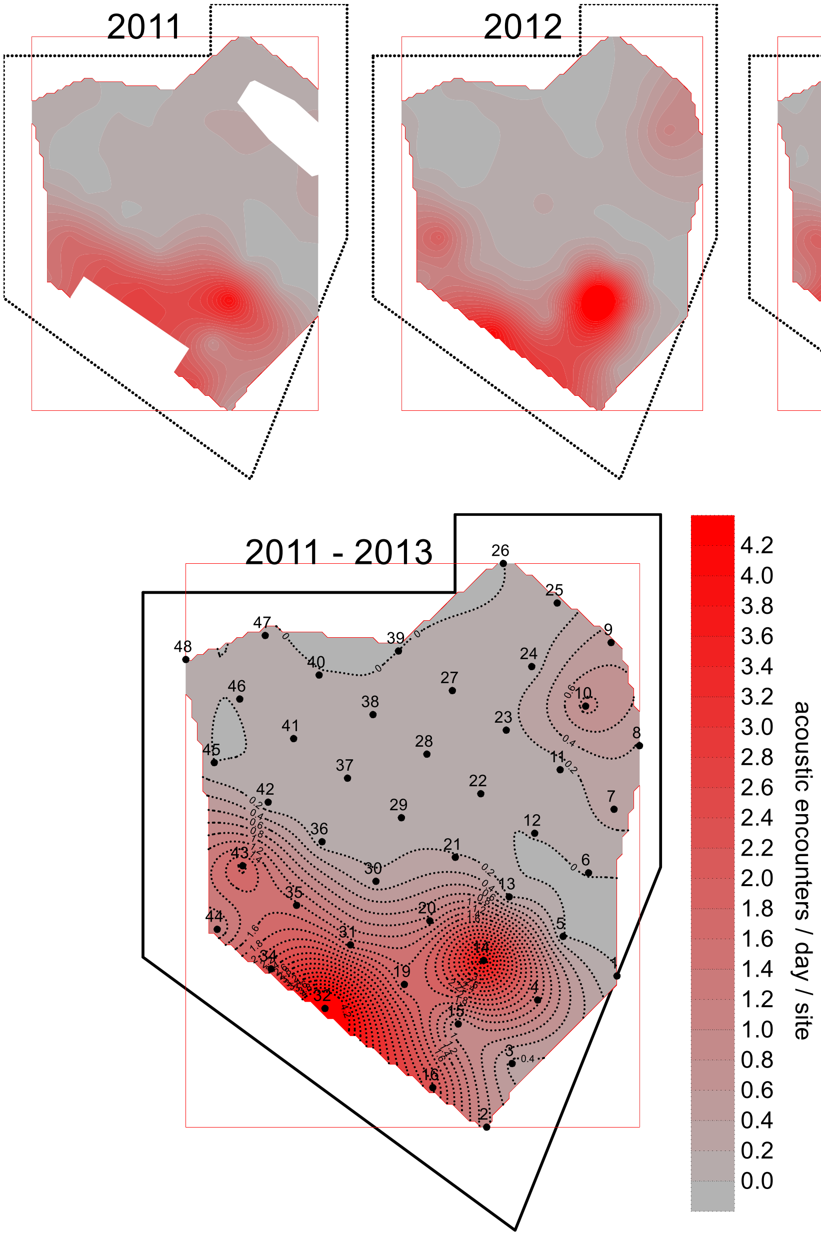

Figure 7. Acoustic encounter rate contour maps based on data for every sampling year and all data combined. Raw encounter rate data are smoothed by Kriging. The map for all data (i.e., all three years) shows the position of the sampling sites. The results illustrate the heterogeneous distribution of the encounter rate and the areas of highest acoustic activity around sites 14 and 32.

Trends Using Raw Data

Based on three sampling seasons the investigators have analyzed a total of 127 site-years; a site-year describes the data collected at one site over a one-year period. The data cover 9,817 complete site-days and include 6,270 acoustic encounters with one or more vaquitas.

An acoustic encounter is defined as any series of identified clicks separated by no silent intervals longer than 30 minutes. Table 2 shows the raw data for all metrics considered.

Table 2. Total effort and different measures of acoustic detection including DPM and encounters.

	2011	**2012**	**2013**	***Total***
Sites per year	39	45	43	*127*
Site-days	3,019	3,785	3,013	*9,817*
DPMs	8,665	9,766	6,897	*25,328*
Encounters	2,151	2,374	1,745	*6,270*
Average DPM / site / day	2.91	2.69	2.29	*2.64*
Average encounters / site /day	0.71	0.63	0.58	*0.64*

The raw annual percent change is given in Table 3 for each of the metrics discussed. As can be seen in Figure 3 the decline from 2011 to 2012 estimated from the raw data will underestimate the actual decline because 2011 was missing some of the C-PODs expected to have high numbers of vaquita detections.

Table 3. Estimated percent change in annual vaquita abundance using encounters/day and DPM/day and based on the raw data. All the measures indicate strong declines in vaquita detections and, therefore, abundance (Figure 1 presents the same information graphically).

	2011 to 2012	2012 to 2013	2011 to 2013
Encounters/day	-11.3%	-7.9%	-18.3%
DPM/day	-7.5%	-14.9%	-21.3%

Figure 1 shows the DPM metric in Table 3 as a bar chart. All indicate strong declines in vaquita detections.

<u>*Stochastic Model of Acoustic Activity*</u>

The measures of vaquita acoustic activity (encounters/day or DPM/day) are essentially count data. The encounter rate data are over-dispersed relative to a Poisson distribution: approximately 75% of the data were zero, and the ratio of variance to mean was about 4 to 1 (Appendix 1). An analysis by Jaramillo indicates that the negative binomial distribution fits the encounter rate data adequately (Figure 8). Additional research should be undertaken to investigate whether this distribution also would fit the DPM data.

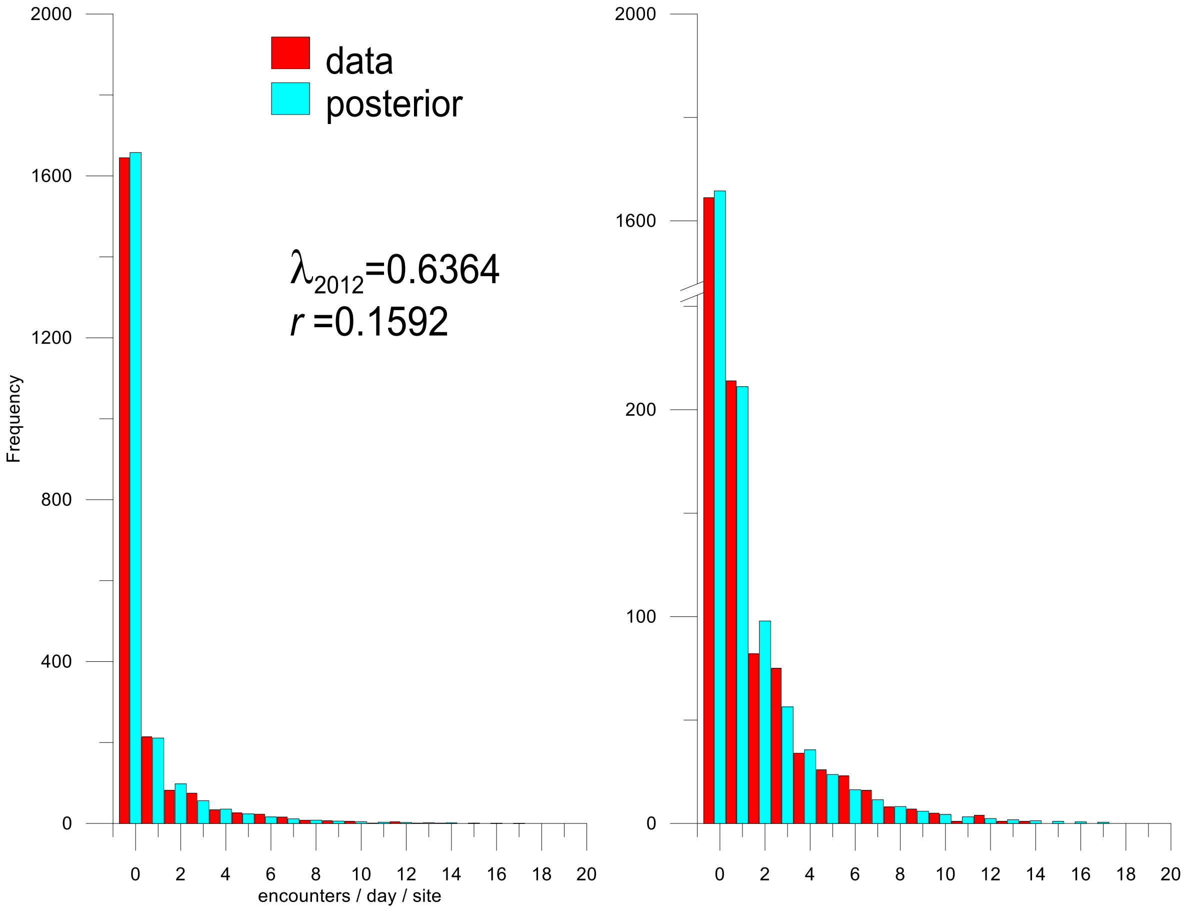

Figure 8. Histograms of data (encounters/day for 2012, red bars) compared to model-predicted rates (posterior probabilities multiplied by total encounters, blue bars). The plot on the right has a discontinuous y-axis to show more detail for the non-zero data. λ is the mean and r is the dispersion parameter of the negative binomial distribution.

Models to Adjust for Uneven Spatial Effort

Several analytical models were used to adjust the raw data for uneven spatial effort in different years. Jaramillo examined three alternative approaches to address this spatial-temporal inconsistency. First, he used data only from those days and sites where monitoring effort occurred each year. That approach was less than optimal because it greatly reduces the amount of data. Second, he used a Bayesian polynomial model of encounter rate (see details in Appendix 1 and summary of results in Table 4), and third, he created another analytical model that treated each station as a categorical variable (see details in Appendix 3). The last of those approaches estimated a 19.9% decline per year.

Table 4. Results from Bayesian modeling (needs adjusting to show different results for encounter rate and DPM for 3rd degree only…needs explanation)

Model	Min	Max	Average	Median	Std dev	Equal Tail Interval		Highest Density Interval		Credibility value <0
Simple (Encounters)	-0.3834	0.0334	-0.1771	-0.1770	0.0484	-0.2723	-0.0825	-0.2706	-0.0810	0.9999
Linear (Encounters)	-0.2147	0.0465	-0.0851	-0.0851	0.0308	-0.1455	-0.0246	-0.1449	-0.0242	0.9971
Second order (Encounters)	-0.2206	0.0491	-0.0903	-0.0903	0.0313	-0.1521	-0.0289	-0.1521	-0.0290	0.9980
Third order (Encounters)	-0.2440	0.0295	-0.0932	-0.0930	0.0310	-0.1540	-0.0322	-0.1542	-0.0325	0.9988
Third order (DPM)	-0.2642	0.0178	-0.1263	-0.1263	0.0346	-0.1944	-0.0577	-0.1956	-0.0593	0.9998

The Committee noted that the one-dimensional polynomial models used to describe geographic differences in relative abundance did not completely capture the geographic patterns in the contour maps of the raw data (Appendix 1, Figure 7). Barlow suggested using Generalized Additive Models (GAMs) with two-dimensional splines to correct that shortcoming. Jaramillo provided Barlow with the data he used in his Bayesian analyses, and Barlow completed the GAMs overnight. Barlow modeled both acoustic encounters per day (as defined by Jaramillo, see Appendix 1) and DPM (also summarized on a daily basis) and created models for year alone (without geographic components), for year plus a 2-dimensional smooth plate spline, and for year plus site (C-POD station number) as a categorical variable. He used Simon Wood's R package (*mgcv*) for all model fits assuming a negative binomial distribution for the acoustic indices of vaquita abundance (R code is available Appendix 4).

The GAMs analyses (Table 5) confirmed the declines that were seen in Jaramillo's Bayesian models, but indicated rates of population decline that were generally higher than presented in Table 4 and Appendix 1. Models with just time (year) and with time & tide showed decreases of 10-12% per year. When geographic differences in vaquita abundance were added to models (either as a 2-D spline fit of latitude/longitude or as a categorical factor for C-POD station number), the results indicated rates of decline of 20-26% per year. The 20% decline per year is similar to the Bayesian model of encounter rate based on categorical station numbers. For direct comparison to Jaramillo's Bayesian polynomial model, Barlow fit a GAMs model using 3rd-degree polynomials of latitude and longitude (separately) and linear effects of time and tide. The results indicated slightly higher rates of decline (~10% per year) than the median values of the Baysian model but much lower rates of decline than were seen with 2-dimensional spline fits.

The GAMs with 2-dimensional spline fits to latitude & longitude explained the geographic patterns in the acoustic data better than the polynomial model, as indicated by the higher percentages of explained deviances (Table 1). The geographic model of relative vaquita abundance (Figures 9 and 10) also better captured the patterns of geographic distribution seen in the smoothed contour plots (Appendix 1, Fig. 7).

Table 5. Estimated decline in vaquita abundance based on GAMs analyses of encounters per day and DPM per day. Results include the exponential annual rate of population change (r) and its standard error and the percent explained deviance for each model.

Model	**Encounter rate**			**DPM**		
	r	**se-r**	**% ExplDev**	**r**	**se-r**	**% ExplDev**
Year	**-0.109**	**0.021**	**0.2**	**-0.128**	**0.015**	**0.2**
Year + tide	**-0.108**	**0.029**	**0.3**	**-0.127**	**0.015**	**0.3**
Year + 2D-spline(Lat*Long)	**-0.234**	**0.027**	**55.5**	**-0.295**	**0.022**	**57.2**
Year + categorical station	**-0.219**	**0.028**	**57.7**	**-0.277**	**0.022**	**59.9**
Year + poly(Lat,3) + poly(Long,3) + Tide	**-0.104**	**0.024**	**32.1**	**-0.101**	**0.018**	**30.6**

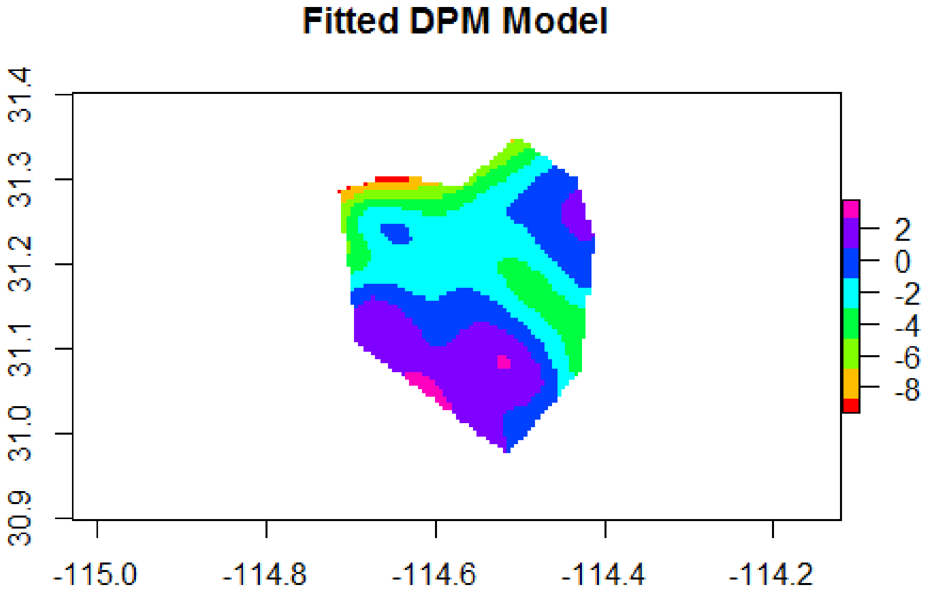

Figure 9. Relative abundance of vaquitas based on a GAMs analysis using a 2-dimensional smooth plate spline fit to DPMs per sample day from 2011-2013 C-POD monitoring stations. The smoothed values are truncated at the edge of the achieved grid of sampling stations.

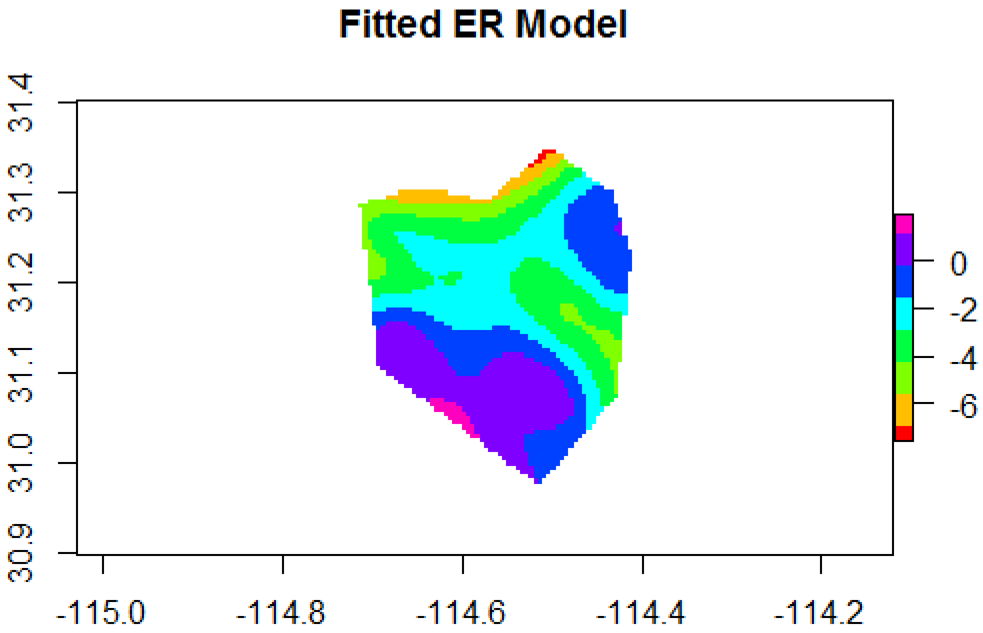

Figure 10. Relative abundance of vaquitas based on a GAMs model using a 2-dimensional smooth plate spline fit to acoustic encounters per sample day from 2011-2013 C-POD monitoring stations. The smoothed values are truncated at the edge of the achieved grid of sampling stations.

The Committee asked whether the spatial model would show changes in the rate of decline between the two time periods (2011-2012 and 2012-2013). To address that question, Barlow used GAMs models with a spline fit for year and a 2-dimensional spline fit for latitude & longitude. The results (Figure 11) indicated that the rate of decline was higher during the first time period than during the second for both measures of acoustic density (encounters and DPMs per day).

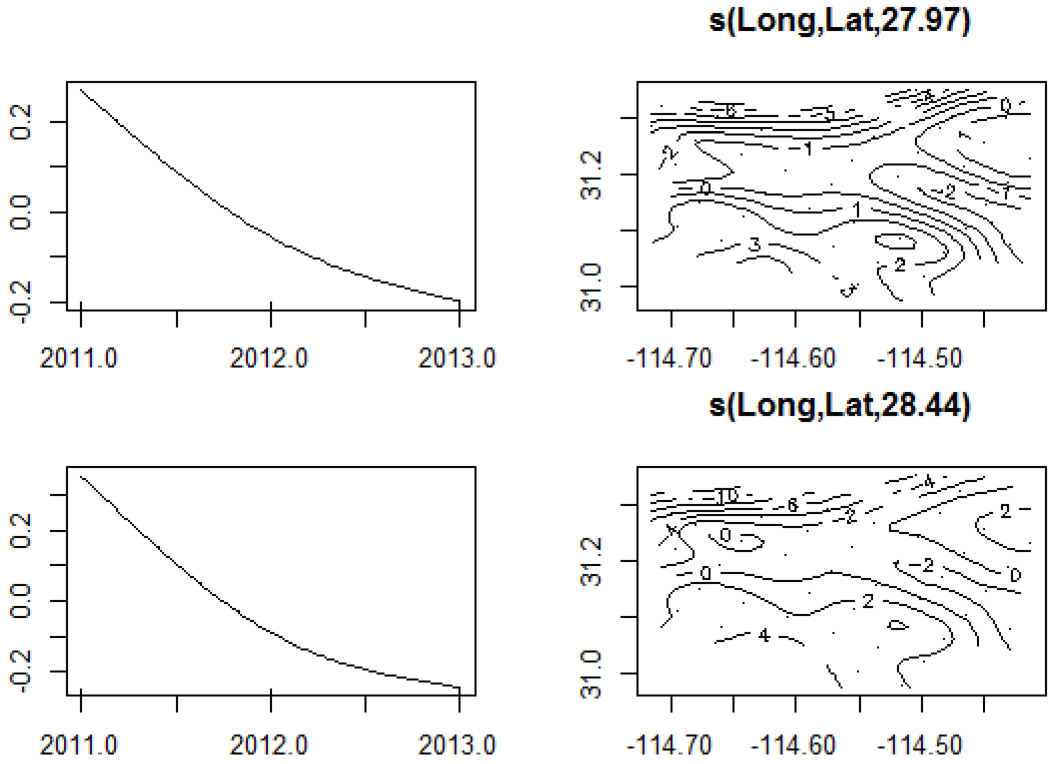

Figure 11. Encounter rate (top) & DPM (bottom) smooth spline fits of year and lat/long.

Table 6 summarizes the results of these different models for encounter rate (the metric with complete results for the Bayesian analyses). For the model types that were run using both the Bayesian and likelihood approaches (GAMs), the rates of decline were similar. The estimated rate of decline from the polynomial model differs substantially from the results of the other models, indicating that the polynomial model may not adequately reflect the spatial complexity of the data.

Table 6. Rates of decline (r) and precision for different models and different statistical approaches.

	Bayesian		Generalized Additive Model	
Model	r	SE	r	SE
Simple	-0.171	0.048	--	--
Categorical	-0.222	0.028	-0.196	0.027
2-D spline	--	--	-0.209	0.027
Polynomial	-0.093	0.031	-0.099	0.024

Refining our Understanding of the Trend Models

All the above-described analytical results indicate that vaquita abundance is declining rapidly. A decline on the order of 8-10% annually would be sufficient to call for strong and swift management action. A decline on the order of 20% would warrant an even stronger response including drastic measures to halt the decline and prevent imminent extinction.

Because the results presented here have potentially grave implications for conservation efforts, the Committee is calling for their immediate review. Specifically, the Committee recommends the following steps be taken immediately.

> 1) The investigators write descriptions of the models summarized in this report with sufficient detail to allow replication by independent analysts,
> 2) They put the data in files for analysis using the 3 different metrics discussed,
> 3) The Committee selects an expert panel of at least 3 statisticians and modelers,
> 4) The investigators send the data and model descriptions to the expert panel so they have at least 2 weeks with the materials,
> 5) The Committee convenes the expert panel to work together (preferably in person but potentially remotely) with the appropriate members of the Committee to write a report with the objective of providing an estimate of the current rate of decline.

The following modelers were suggested as appropriate for this important task: Len Thomas, Justin Cooke, Jeff Moore, Andre Punt, Russell Leaper, Jay Ver Hoef and Jeff Laake. These modelers would work with Armando Jaramillo and Jay Barlow from the Committee. The Committee believes this work must be completed by June 30.

Recommendations for the 2014 Acoustic Monitoring Season

The Committee was very satisfied with the deployment and retrieval of C-PODs within the Refuge. However, it also believes that vaquita distribution near the southern border warrants more study. The visual data (Figure 1 and Figure 12) show a low density right next to the southwest boundary in an area not currently monitored with C-PODs. Because maintaining C-PODs on the boundary buoys has been unsuccessful and experimental C-PODs put just outside the Refuge were all lost, the Committee recommends adding 5 C-PODs in the southern area inside the Refuge where visual detections were low to ensure that the vaquita movement outside the Refuge has not contributed to their apparent decline. The Committee also recommends increasing enforcement along this boundary during the monitoring season and replacing C-PODs frequently during the season to obtain as much data as quickly as possible. In addition, the Committee recommends deploying the PROFEPA mother ship to the southernmost tip of the Refuge during the monitoring season and requesting deployment of a C-POD from the ship. Finally, the Committee recommends forwarding to CIRVA and the Presidential Commission on Vaquita the idea of paying fishermen to deploy C-PODs for daily periods just south of the Refuge. The data collected would help construct better boundaries for the Refuge and improve confidence that trends estimated from the acoustic monitoring project are representative for vaquitas.

Summary of Committee Recommendations

- Increase enforcement including along the southern boundary during the monitoring season
- Adding 5 C-PODs in the southern area just inside the refuge
- Paying fishermen to deploy C-PODs for daily periods just south of the refuge during monitoring season
- Publishing a technical note on the successful methods developed to moor and retrieve C-PODs using light-weight, inexpensive materials
- Making new visual display developed by Jaramillo for C-POD to facilitate C-POD analysis publicly available

- Test sensitivity of analytical results to the type of metric rates used (encounters, detection positive minutes, clicks)
- Immediately advancing analysis of results using independent analysts in an expert panel

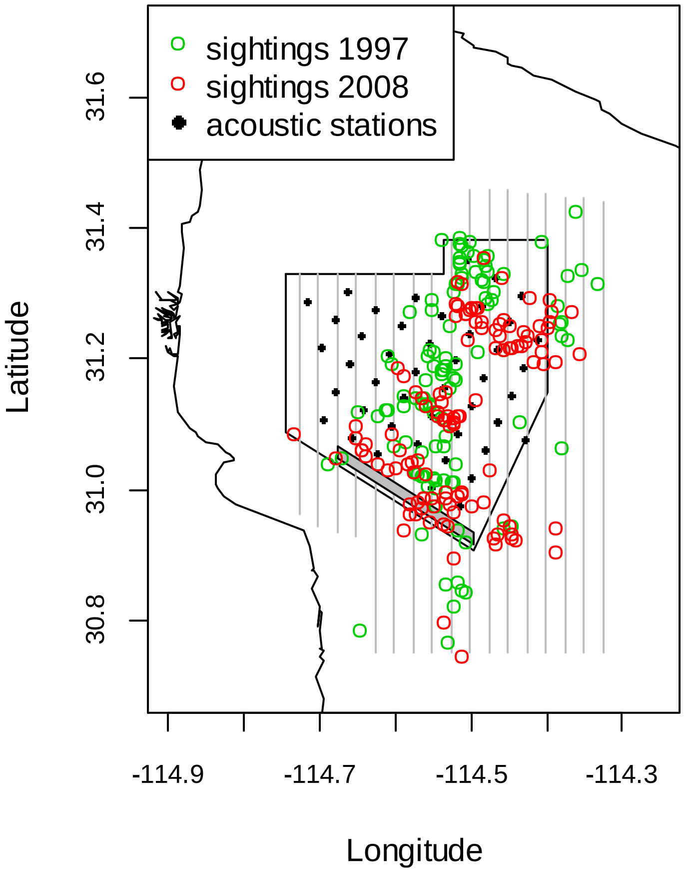

Figure 12. The locations of the 5 new C-PODs should be within the gray box shown inside the Refuge along the southwest boundary. The C-PODs should be placed as close to the boundary as is safe from fishery entanglement, which would include areas of low visual detections (in the middle of the southwestern boundary) and high visual detections (towards the southern tip of the Refuge).

Acknowledgements

The workshop was funded by US Marine Mammal Commission. The research was funded between 2010 and 2013 by Mexico Minister of Environment, Instituto Nacional de Ecologia, The Ocean Foundation, Fonds de Dotation pour la Biodiversité, Cousteau Society, WWF México, WWF US, The Mohamed bin Zayed Species Conservation Fund and Barb Taylor.

Appendix 1

VAQUITA POPULATION TREND MONITORING PROGRAM BASED ON PASSIVE ACOUSTICS DATA

PROGRESS REPORT FOR

STEERING COMMITTEE

SECOND MEETING

Ensenada, B.C., México
April 24-25, 2014

1. Introduction

This report presents partial results of an investigation aimed at estimating the population trend of the vaquita, through monitoring of individuals of the species with passive acoustic techniques, as designed by a group of experts (Rojas Bracho et al., 2010).

This monitoring progam is based on the installation of autonomous acoustic detectors, named C-POD, at 48 sites within the Refuge for Protection of Vaquita and buoys used to delimitate it. Given illegal fishing activities that happen inside the refuge, the 48 sampling sites were restricted to the three months before the shrimping season (June to September) when fishing intensity is the lowest of the year. Efforts have been made to continue sampling all year-round with detectors deployed in the buoys. However, we have experienced loss rates that are not sustainable. This report describes the different alternatives of mooring methods essayed that have failed, as well as a recent attempt to solve this problem.

In its current development, the monitoring program envisages the attainment of six years of sampling, in order to detect small increases or decreases of the population during this period. This information is essential to adjust the actions taken by the Mexican government to recover the species. If population is not monitored directly, given its critical current level, it could reach very low numbers before the recovery program is adjusted in a timely manner.

This report presents data obtained during the first three years of sampling, and depicts the analysis done until now. It includes the identification of vaquita acoustic events and the implementation of a model to estimate the acoustic encounter rate trend in relationship with time, as an index of population trend.

2. Field activities

2.1. Acoustic detectors deployed on delimiting buoys of Protection Refuge

The only feasible way to gather acoustic data all year round, in order to understand distribution patterns of vaquita acoustic activity, is to deploy acoustic detectors in the buoys delimiting the Protection Refuge (Figure 1A). Until now three mooring methods have been essayed, all with poor results in terms of equipment recovery.

The first method (Figure 1B) consisted in a metallic frame attached to the buoy chain, which was the platform to moor the acoustic detector. Using this method 13 moorings were deployed on July (6) and September 2011 (remaining 7), in buoys 1, 2, 3, 5, 6, 7, 8, A, B, C, F, G and I (Figure 1A). Buoys 4, D and E were not in place previous to deployment. During December 2011 and January 2012 it was tried to retrieve the acoustic detectors. At first, according to plans, it was tried to grasp the line holding the detector (Figure 1B) with a hook inserted in the tip of a pole. This was successful only at Buoy 8. Further inspection using submersible camera and diving evidencing interaction with fishing or directed sabotage, finding no frames or frames detached of the chain, as well as entangled gillnet pieces (Figure 1C). Diving in the buoys resulted in the recovery of an additional detector in Buoy 2. Fishermen delivered later the acoustic detectors deployed in buoys 1 and A. Hence, only one out of 13 detectors was recovered in the proper way.

After the failure of the method described above, it was essayed to mooring acoustic detectors directly to the buoy chain using a snap shackle (Figure 1D). This was made by SCUBA diving. During this activity it was possible to check the buoys for the situation of the moorings described above. During January 31st and February 1st, 2012, twelve detectors were deployed at buoys 1, 2, 3, 5, 6, 7, 8, A, B, F, G and I. Buoy C was not in place, in addition to ones at sites 4, D and E. On March 23rd, almost two months after deployment, it was possible to recover the detector at Buoy G, which was replaced by another with fresh batteries. On April 28th it was tried to recover detectors at buoys 2, 3, 5, 6, B and I, recovering only the one at Buoy 5, finding again evidences of fishing operations or directed theft. In fact the recovered detector was entangled in several folds of a net. Buoy F was removed for maintenance by PROFEPA, which delivered the detector deployed there to Biosphere Reserve. The one deployed at Buoy 8 was found by Biosphere Reserve personnel floating nearby. During May it was unsuccessfully tried to recover the reminder detectors at buoys 1, 7, A, B as well as the one redeployed in Buoy G during March. Summarizing, not accounting for Buoy F, it was possible to recover detectors only on two of the eleven buoys, although the detector redeployed at Buoy G was finally lost.

The mooring method depicted above was of difficult implementation, as it is needed diving to deploy and retrieve detectors. An alternative method is depicted in Figure 1E. A rope is attached to the weight holding the buoy and is hold extended with an anchor, where another rope is used to hold the acoustic detector. The rope is extended inside the

Protection Refuge. The installation of the rope in the weights is not a job for amateurs, since it is a deep diving under extreme turbidity. As such, it was required the hiring of professional divers. To retrieve detectors a hook is towed behind a boat to grasp the rope and pull it to reach the detector. This method is thus similar to that used in the moorings that are deployed within the refuge (see next section). However, it will be not required to waste time searching for the rope with GPS positions, because the buoy marks the position clearly.

During September 7 to 9, 2012 (just previous to shrimp season), 11 moorings were placed on buoys 1, 2, 3, 5, 6, 7, 8, A, I, F and G (Figure 1A). The field operations team worked together with the divers. Once the diver went down and attached the rope to the buoy, a small boat was used to extended rope, into the Refuge, and threw the anchor along with the acoustic detector. The team stayed at the site for several minutes to ensure that all the rope gets submerged, without any sign on the surface.

Some days after the deployment PROFEPA removed buoys A and I for maintenance and bring back acoustic detectors, which gather, respectively, only 6 and 14 days of data. Efforts to recover the acoustic detectors were done first on November 22nd and five of the moorings were properly grasped and detectors retrieved (buoys 2, 5, 6, 8 and F). On December 14th one additional detector was retrieved at Buoy G and few days later a fisherman delivered the detector deployed at Buoy 7. Moorings at buoys 1 and 3 were not located after about two hours of searching effort. Hence, not accounting buoys A and I, six out of the nine detectors deployed were properly located and retrieved, even in areas subjected to intense fishing operations.

After December 2012, detectors with fresh batteries were deployed at the buoys where moorings were found (2, 5, 6, 8, F and G). Unfortunately, by March 2013 none of the detectors were found. Hence, although after the first retrieving period the mooring method looked promising, it is evident that we still do not have a robust method to sample all year round in buoys.

As it is important for the monitoring program to gather data about distribution of the acoustic activity of vaquita all year round, and the deployment in buoys looks as the only feasible way to do it, a fourth mooring method was essayed on March 11th 2014. The same approach depicted above (Figure 1E) was used, but replacing all the materials with stainless steel, without any hand removable parts, supposing ropes were cut on the past trials. A couple of moorings were deployed in buoys G and I using SCUBA diving, holding the wire at about 15 meters below the surface. As the wire must tend to get buried into the bottom sediments, holding the wire not as close the bottom as in the past trials could help to properly grasp the wire during equipment retrieval. No acoustic detectors were placed in the mooring, waiting to review if moorings stay in place intact.

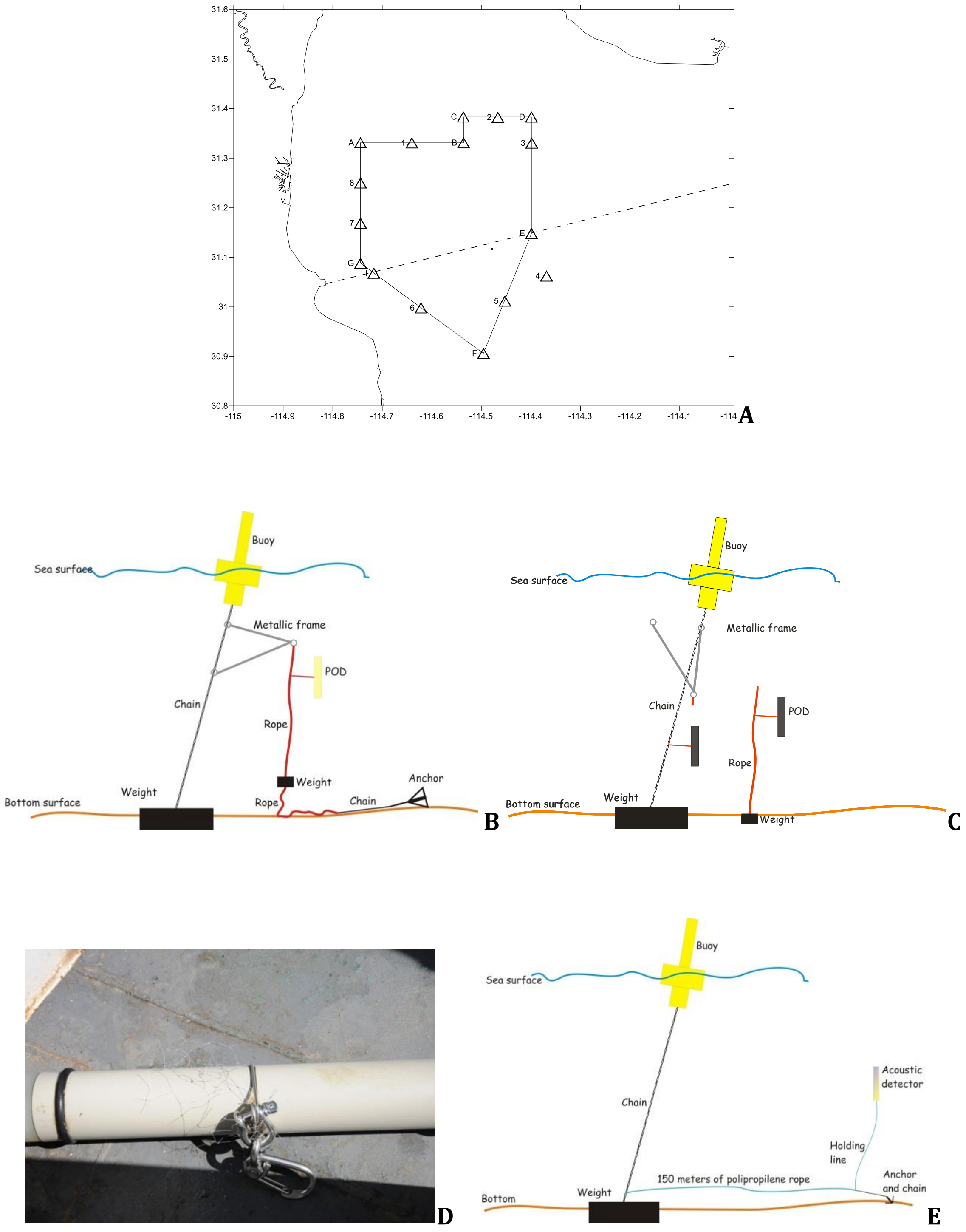

Figure 1. A) Map showing the polygon of Vaquita Protection Refuge (solid line) and delimiting buoys (triangles). Broken line represents the seaward boundary of the Biosphere Reserve. B) First method to deploy acoustic detectors on buoys. C) How first method failed and way to mount detectors directly to buoy chain. D) Shackles used to mount CPOD to chain. E) Method to mooring detectors using a long rope attached to buoy weight.

On April 12th the moorings were inspected. The one deployed at Buoy I was found after four attempts to grasp the wire, passing relatively close to the buoy. The one at Buoy G was not found after several passes at different distances from the buoy. It will be required to dive in the site to determine if it was stolen, moved by fishing operations or not effective anchoring, or because the wire got buried too deep in the sediments. The pieces of the mooring deployed at Buoy I look in good shape after one month of service, confirming the quality of the stainless steel used (Figure 2).

After reviewing by diving the mooring at Buoy G, as well as to review again the one at Buoy I, it will be decided the next steps. In case to find that moorings are there, other ones will be deployed at other buoys to continue with the trial, but no actual detectors will be used until determine that the design can assure the recovery of them.

Figure 2. Detail of river anchor**,** wires and lock used to construct the moorings to deploy acoustic detectors in the buoys delimiting the Protection Refuge for Vaquita. After one month of soaking it do not appears any trace of stain or damage.

2.2. Acoustic detectors deployed inside Protection Refuge

The moorings used to deploy acoustic detectors inside Protection Refuge are alike the ones used to deploy in Refuge buoys (Figure 1E). A main polypropylene rope, about 150 meters long connects two anchors with chain at every side. One of them is Danforth style and the other river kind. On the side of the river one a rope is connected which holds a small rigid buoy and acoustic detector (Figure 3). A piece of chain is placed in the middle point of the main rope to hold against the bottom, as the material has positive floatation and during trials the rope was visible in surface on some occasions.

The procedure to deploy the mooring and detector starts by launching the Danforth anchor at the sampling site. At the same time the geographical position is recorded in a handheld GPS. Then the boat is moved to the east in order to extend the line until it is determined that the anchor is resisting the pulling. At that time the river anchor is launched together with the holding line and detector. Again, position is recorded in GPS. The retrieval of the moorings is done by trawling a grasping hook behind the boat, using to navigate the GPS positions recorded at the time of deployment.

After three years of sampling the field operations team (three boats) has developed enough skills to efficiently do the job. On deployment every boat carries seven or eight moorings per trip, so the job can be completed in two days. On retrieval every boat recovers approximately five moorings per day. The technique is so refined that finding of the mooring main line takes in average 20 minutes since deployment of hook until grasping. Took the mooring on the boat takes another 20 minutes using human and boat power. Hence, it is considered that mooring method used inside Protection Refuge is working well and is not necessary to change anything.

In 2011, first year of formal sampling inside Refuge, moorings and detectors were deployed in the 48 sampling sites designed during 2009 Workshop (Rojas Bracho *et al*., 2010; Figure 4) between June 5 to 9. Operations to locate and retrieve then were carried out between September 9 and 25. During the first two weeks 38 of the 48 moorings deployed were located and retrieved, one of them without the acoustic detector (Figure 4). A couple of detectors were delivered to the staff of the Biosphere Reserve previous to the start of recovery tasks (sites 2 and 9; Figure 4), therefore there was no search effort at these sites. The CPOD deployed at site 45 was delivered during January 2012. The one deployed at site 3 was recovered during the retrieval of equipment deployed during 2013 sampling season. Six of the moorings were never found.

On early May 2012, we obtained information about the presence of dozens of fishing boats within the Refuge, sighted during a survey flight[1]. Accordingly, it was decided to delay the deployment of detectors waiting for a reduction of fishing intensity. By June, we were reported that only a few boats had been found, so it was decided to install the detectors by the middle of this month.

All 48 moorings of the monitoring program (Figure 4) were deployed between June 17 to 20. The field work to recover the moorings was carried out between September 17 and 22. A total of forty one moorings and detectors were recovered (Figure 3). One detector was delivered by a fisherman and the ones deployed at sites 11, 15 and 45 were recovered during the retrieval of equipment deployed during 2013 sampling season. As in 2011 sampling season, moorings at sites 17, 18 and 33 were not found.

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[1] Juan Manuel García Caudillo. Project "Assessment of the effects of the productive and technological reconversion program PACE: Vaquita, on the number and space-temporal distribution inside the refuge for the protection of vaquita and Biosphere Reserve Upper Gulf of California and Colorado River Delta". Pesca Responsable y Comercio Justo S. de R.L. de C.V. Blvd. Zertuche 937-3, Valle Dorado, Ensenada, B.C., México 22890.

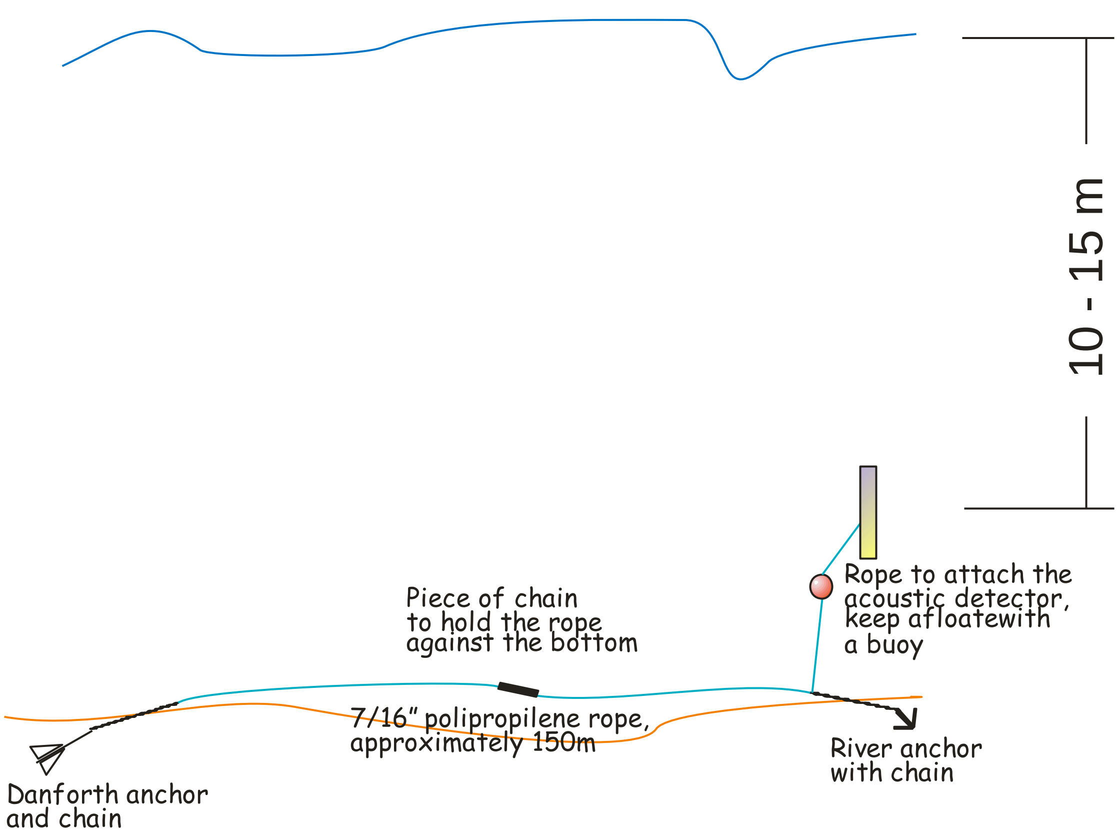


Figure 3. Sketch of the moorings used to deploy acoustic detectors inside Protection Refuge of Vaquita. The basic idea is to connect two anchors with a long rope that can later be grasped by means of a hook trawled behind a boat. No traces of the mooring are visible in surface in order to avoid theft. Location of anchors are marked in GPS that help later to know where to navigate to grasp the rope. A rope to hold the CPOS is attached to the side where river anchor is.

It was decided not to deploy equipment at these sites during the 2013 sampling season, in order to avoid more equipment. Two of these sites are in the southwest boundary of the Vaquita Refuge and the other close to. Hence, frequent fishing operations could be the reason for the lost. After being informed of the reduction of fishing boats in the area, 34 moorings were deployed between June 15 and 16. Due to bad weather conditions the deployment of the reminder moorings took place on June 22 (7 moorings) and July 13 (4 moorings). The field work to recover the moorings was carried out between September 9 and 12. A total of 39 moorings and detectors were recovered (Figure 4). On September 20 other detector was recovered. On October 1st, a coordinated effort of three boats working side by side to cover more area, resulted in the additional retrieval of four detectors. Of the 45 moorings deployed only the one at site 3 was not located, which represents a loss of only 2.22%. It is far the most successful sampling until now in regards to the loss of moorings in the field, not taking into account the three sites where no deployment occurred.

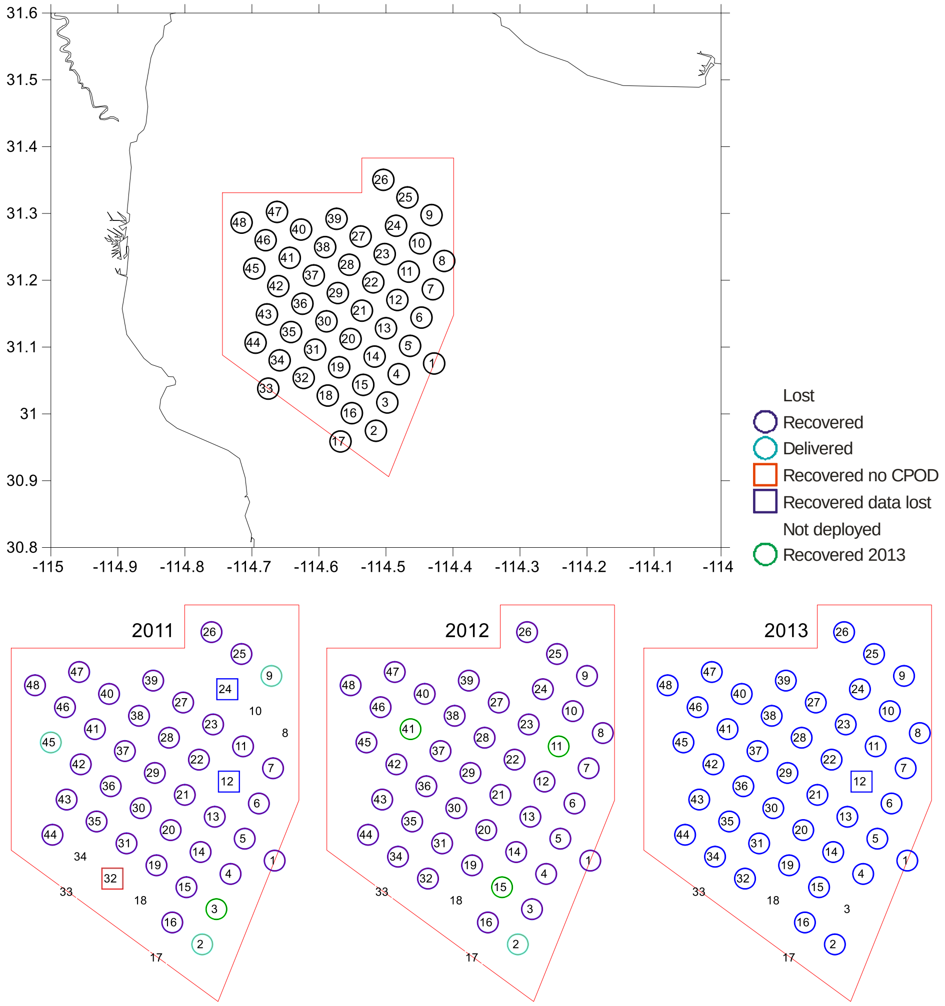


Figure 4. Position of the sampling sites inside Vaquita Protection Refuge (upper map, numbered circles). Below are the results of moorings and acoustic detectors recovery on the three past sampling seasons. Sites not enclosed by any symbol are places where no moorings were found or sites where no moorings were deployed, Circles indicate places where data is available and squares sites where moorings were recovered without detector or detectors recovered without data.

3. CPOD performance

Inside the Protection Refuge for Vaquita have been deployed a total of 141 moorings and acoustic detectors. 128 of them have been recovered by means of the planned routine or delivered back by other persons. This represents a recovery rate of 90.78%.

CPODs store data in a 4GB SD card, into 4 files near 1GB the first three and a fourth smaller due to the presence of the settings file. The files are populated in order from 0 to 3 as data is gathered. Along the three years of sampling already completed only on 27 times had been necessary to use the fourth file (Table I). When this has happened, on 22 occasions (81%) this file has been damaged. In few occasions reformatting of the card with the dedicated program has resulted in few days of additional data. The fourth file has been necessary mainly on sampling sites at the northern portion of the Protection Refuge, where waters are shallower and noisier.

On other occasions the CPODs have recorded few days of data. As the equipment is deployed by three months at least, it is considered that gather less than 60 effective days is low. Gather less than 50 days is too low. In total less than 60 days of data have been gathered on 23 times, 10 of them at a very low level, including a case of gather only five days (Table I) noting that the angle never changed its turned off angle position. Only on six of these occasions have coincided with a damaged fourth file (Table I), all at a low level. All the very low days of data cases occurred during 2013. Again, these events tend to occur on shallow and noisy areas, except for the very low data cases that occurred in 2013. The cause of this must be investigated.

In total occurred 44 events of abnormal data gathering, which represents 34% of the total sampling inside Protection Refuge along the three years. A matter of concern is raised at noisy areas as well as the very low volumes of data gathered at some sites during 2013. It must be discussed during the second meeting of the Steering Committee.

4. Row data analysis

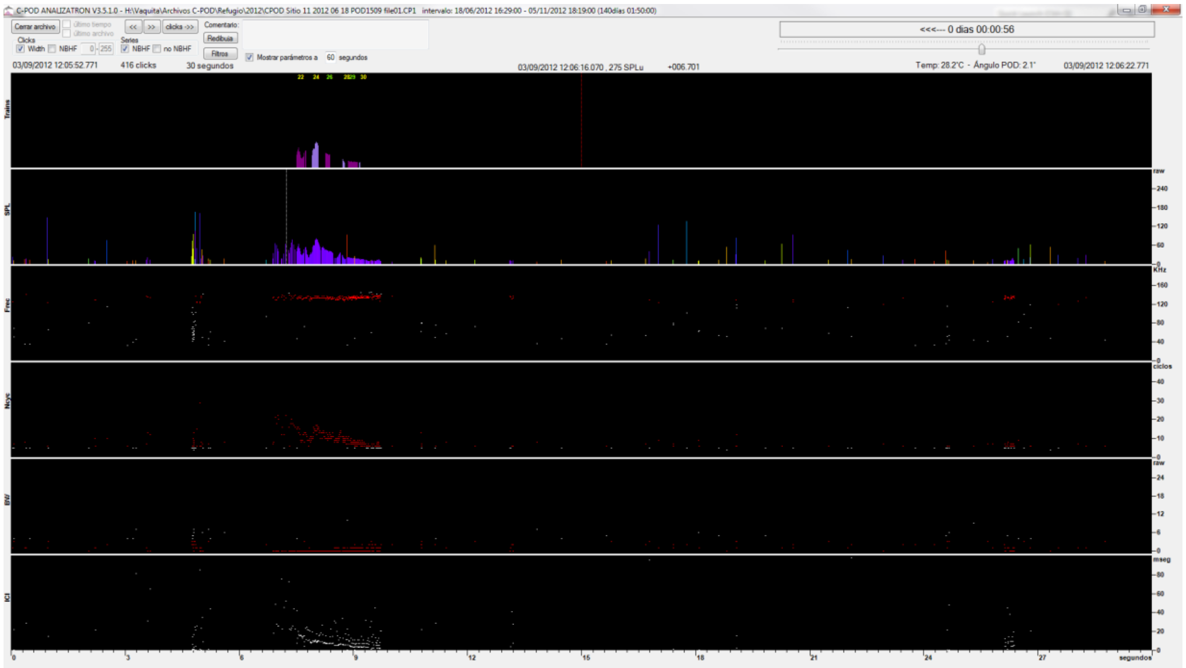
Specialized CPOD program provided by the manufacturer of the equipment (Chelonia Limited) was used to identify Vaquita like click series. Every CP1 file is analyzed with KERNO classifier, which identifies series with narrow band high frequency (NBHF) clicks, potentially emitted by vaquitas, as well as wide band signals potentially emitted by other cetaceans like dolphins, sonars or other sources. This process creates CP3 files, which only contain information of the identified series, which greatly reduces the volume of data to be reviewed by the analysts.

Two analysts review all CP3 files to decide if the series identified as NBHF by KERNO classifier belong to vaquitas. A number of criteria are defined and recommended by the manufacturer, including click frequency and level, click duration (cycles), click band width, inter click interval and series envelope form. Analysts do not insert new series from inspection of data, but delete the ones not appearing as being emitted by vaquitas. At the end of the review use the export option to create text files containing 1 minute slices with ones if confirmed vaquita series were identified or zero if not. The minutes containing vaquita series are called Detection Positive Minutes (DPM).

Table I. Sites and PODs with events resulting in loss of data. The events are separated by year of sampling. D3 OK means that the fourth data file was written without error. D3 X means the fourth file had an error. Broken means that this POD was returned by a fisherman open and with the electronics board detached. Low means less than 60 days of data gathered but more than 50. For very low level actual number of day are shown. No angle change means that not a single click was stored as the angle of inclination of the POD never changed or the sensor was malfunctioning.

	2011			2012			2013		
Site	**POD**	**Event**	**Days**	**POD**	**Event**	**Days**	**POD**	**Event**	**Days**
2	998	Broken	Low						
6				1341	D3 OK				
8							1336		21
12							1342	No angle change	5
19							1302		12
20							2041		31
21							1301		37
22							1347		Low
26	995	D3 OK		1506	D3 X		2048	D3 X	
27				1501	D3 X	Low			
28	1009	D3 OK		1315	D3 X				
30				1349	D3 X	Low			
31							1338		44
34							1348		13
35							1315		Low
36	1350	D3 X	Low	1316	D3 X		1332		46
37	1342		Low				1316		47
38	1341	D3 X					1337	D3 X	
39	992	D3 OK		1505	D3 X	Low	1331	D3 X	
40	1348	D3 X					2047	D3 X	
41	1349	D3 X					1320		34
42	1343	D3 X	Low	1333	D3 X		1349	D3 X	
44							2040	D3 X	
45	1345		Low	1314	D3 X		1341	D3 OK	
46	1346	D3 X	Low	1309	D3 X		1333		Low
48				1343	D3 X		1311		Low

After the analysis of the first two sampling seasons data (2011-2012) it was noted that the “mechanics” of data displaying in CPOD program is complicated, needing to be changing displays with keystrokes constantly. To reduce this load on the analysts, and try to reduce time and facilitate analysis, a program was created using Visual Studio Express (Microsoft). This program uses the same CP1 and CP3 files to display data using a different “paradigm” (Figure 5). In one screen are presented all the acoustic parameters and click series are identified with color and number codes. Red dotes are displayed when parameter have NBHF like values. The routine to manage series is improved and a text box presents information including the separation in time between series. Comments can be added which are sent to a csv file including a time tag. Log files are created in order to have complete control of the analysis process.



C-POD ANALIZATRON V3.5.1.0 - H:\Vaquita\Archivos C-POD\Refugio\2012\CPOD Sitio 11 2012 06 18 POD1509 file01.CP1 intervalo: 18/06/2012 16:29:00 - 05/11/2012 18:19:00 (140días 01:50:00)

Clicks ☑ Width ☐ NBHF 0 - 255

Series ☑ NBHF ☐ no NBHF

☑ Mostrar parámetros a 60 segundos

03/09/2012 12:05:52.771 416 clicks 30 segundos

03/09/2012 12:06:16.070 , 275 SPLu +006.701

<<<--- 0 dias 00:00:56

Temp: 28.2'C - Ángulo POD: 2.1'

03/09/2012 12:06:22.771

Figure 5. Display of the alternative program written to display CPOD data using a different "paradigm". Top panel shows the contents of the CP3 file, identifying click series and their quality with numbers and colors. Second panel shows the contents of CP1 file. Next panels show, respectively, the click parameters frequency, duration, band width and the inter-click interval. Information area on the top shows controls, general information and the time to the previous series displayed. A box is available to capture comments in a log file.

5. Data 2011 - 2013

A program was written using Visual Studio Express to manage the csv files created by CPOD. This routine identifies the acoustic encounters according to the criterion explained above and creates csv files with the total number of DPMs and encounters per site and day, which is the sampling unit (site-day). After using the alternative analyzing program the CP3 files are read directly to create the csv files with the results.

After three sampling seasons a total of 127 sites have been analyzed, including 9,817 whole days and 6,270 acoustic encounters of vaquitas. An acoustic encounter is defined as all the identified clicks series separated consecutively by no more than 30 minutes. The next table shows data per year:

	2011	**2012**	**2013**	***Total***
Sites	39	45	43	*127*
Days	3,019	3,785	3,013	*9,817*
Encounters	2,151	2,374	1,745	*6,270*

Figure 6 presents these data graphically. The horizontal axis is time and number of encounters per site per day in the vertical one. Every blue point represents the number of encounters in the station-day, in the date when this occurred. The cyan bars represent the distribution of encounter rate (encounters/site/day) per year. It is clear that the sampling units with zero encounters are extremely frequent.

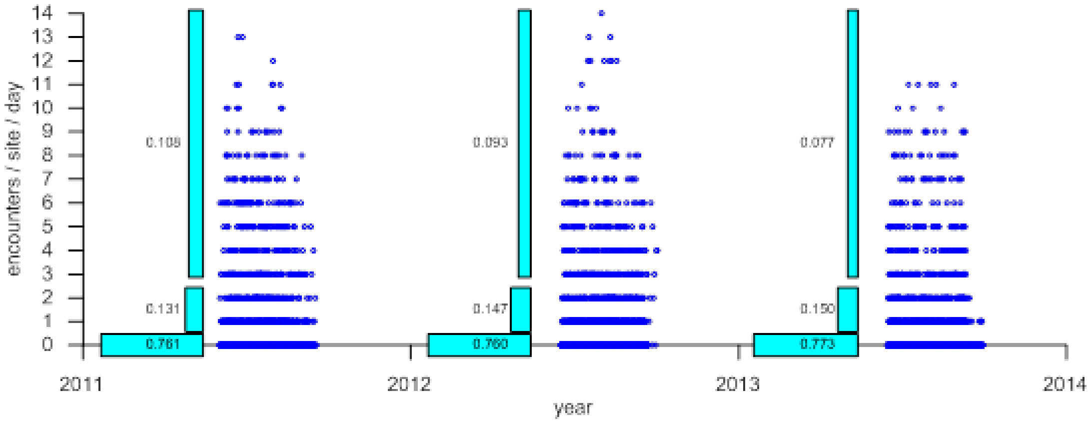


Figure 6. Scatter plot displaying all the data available for analysis. Blue points are individual site days at the date when they occurred. Cyan bars show the proportion of site-days with zero encounters, 1-2 encounters and 3 or more encounters, departing from a Poisson pattern.

6. An approximation to model encounter rate trend

The ratio of the variance over average encounter rate for 2011, 2012 and 2013 data, respectively, is 4.15, 3.94 and 3.82, which clearly departs from a Poisson distribution. Data is then over dispersed or zero inflated as compared with this distribution. Taken this into account, the model approximation used here was made supposing encounter rate data is distributed according to a negative binomial distribution, parameterized as (Ver Hoef and Boveng, 2007; Lord and Park, 2008; Lindén and Mäntyniemi, 2011;):

$$f(y;\lambda,r) = \frac{\Gamma(y+r)}{\Gamma(y+1)\Gamma(r)}\left(\frac{r}{\lambda+r}\right)^{r}\left(\frac{\lambda}{\lambda+r}\right)^{y} \quad \text{.....................} \text{ Equation 1}$$

where y is the value for which calculate the negative binomial probability, λ is the average and r is the dispersion parameter.

The simplest function to model the relationship between encounter rate and time could be, given that the domain of the encounter rate is in the positive numbers is:

$$\boldsymbol{y_t = e^{a+bt}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 2}$$

where y_t is the encounter rate at time t, and a and b are parameters to be estimated. Then, the parameter b determines the change of the encounter rate as the time progress. Negative values of this parameter mean a decreasing rate of the encounter rate, which is an indication of a negative trend of the population, given that no distribution shifts or acoustic behavior changes occur in the same period.

However, this simple model supposes that no other factors affect the encounter rate as measured in the sampling process described in this report.

The acoustic encounter rate is not homogeneously distributed along the Protection Refuge (Figure 7). The northern portion shows the lowest acoustic activity of vaquitas, while the southwest portion has the highest encounter rates. It appears that vaquitas tend to echolocate more frequently around sites 14 and 32, as indicated by the average distribution of the three sampling seasons combined (Figure 7).

The simple model described in Equation 2 could overcome this issue by using a balanced sampling, including data only for days when all sampling stations have data. It occurs because acoustic detectors are not deployed all in the same day, and every one turns off on different days depending on battery duration and data volume gathered. This approach would result in discarding valuable data; hence a better approach is to use a model including the variability due to distribution of encounter rate. On the other hand, it is known that the Upper Gulf of California basin is characterized by a very extreme tidal range, which could result in differential encounter rates between neap and spring tides. A model including all these variables could be used to better understand the encounter rate trend with time:

$$\boldsymbol{\bar{y} = e^{b_0+(b_y y)+(b_{lat} lat)+(b_{lon} lon)+(b_t t)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3}$$

Where $\bar{y}$ is the average acoustic encounter rate given the variables in the model, $\boldsymbol{y}$ is the sampling year (considering the change of acoustic detection rate is negligible during the three months of sampling season), $\boldsymbol{lat}$ and $\boldsymbol{lon}$ are the latitude and longitude of the sampling sites, $\boldsymbol{t}$ is the tide expressed as the difference between the upper and lower tide level of the sampling day, $\boldsymbol{b_0}$ is the intercept parameter of the model and $\boldsymbol{b_y}$, $\boldsymbol{b_{lat}}$, $\boldsymbol{b_{lon}}$, $\boldsymbol{b_t}$ are the parameters (coefficients) determining the relationship between the variables in the model and the acoustic encounter rate.

The relationship between encounter rate with year and tide could be intuitively linear; however the spatial structure seen in Figure 7 is more complicated and could be better modeled with a polynomial. Hence it was essayed the fitting of second and third degree polynomials on latitude and longitude:

$$\boldsymbol{\bar{y} = e^{b_0+(b_y y)+(b_{lat} lat)+(b_{lat2} lat^2)+(b_{lat3} lat^3)+(b_{lon} lon)+(b_{lon2} lon^2)+(b_{lon3} lon^3)+(b_t t)}} \; \ldots.. \text{ Equation 4}$$

Where $\boldsymbol{b_{lat2}}$ and $\boldsymbol{b_{lon2}}$ are the parameters added to the model with second degree polynomials for squared latitude and longitude. Parameters $\boldsymbol{b_{lat3}}$ and $\boldsymbol{b_{lon3}}$ are the case for third degree. The second degree model is the Equation 4 not including the cubic terms.

A Bayesian approach was used to estimate the parameters of the models (Gelman *et al*., 1995; Kruschke, 2011) using non-informative uniform priors for parameters centered at a value of zero. AD Model Builder (ADMB; Fournier *et al*., 2012) was used to estimate posterior distributions using the Monte Carlo Markov Chain (MCMC) routine as implemented in ADMB using the Metropolis-Hastings algorithm (Chib and Greenberg, 1995). Likelihood portion of the joint posterior distribution was based on negative binomial distribution as in Equation 1, considering the dispersion parameter $\boldsymbol{r}$ as and hyper-parameter to be estimated, using a semi-informative uniform prior bounded between 0.01 and 5.00.

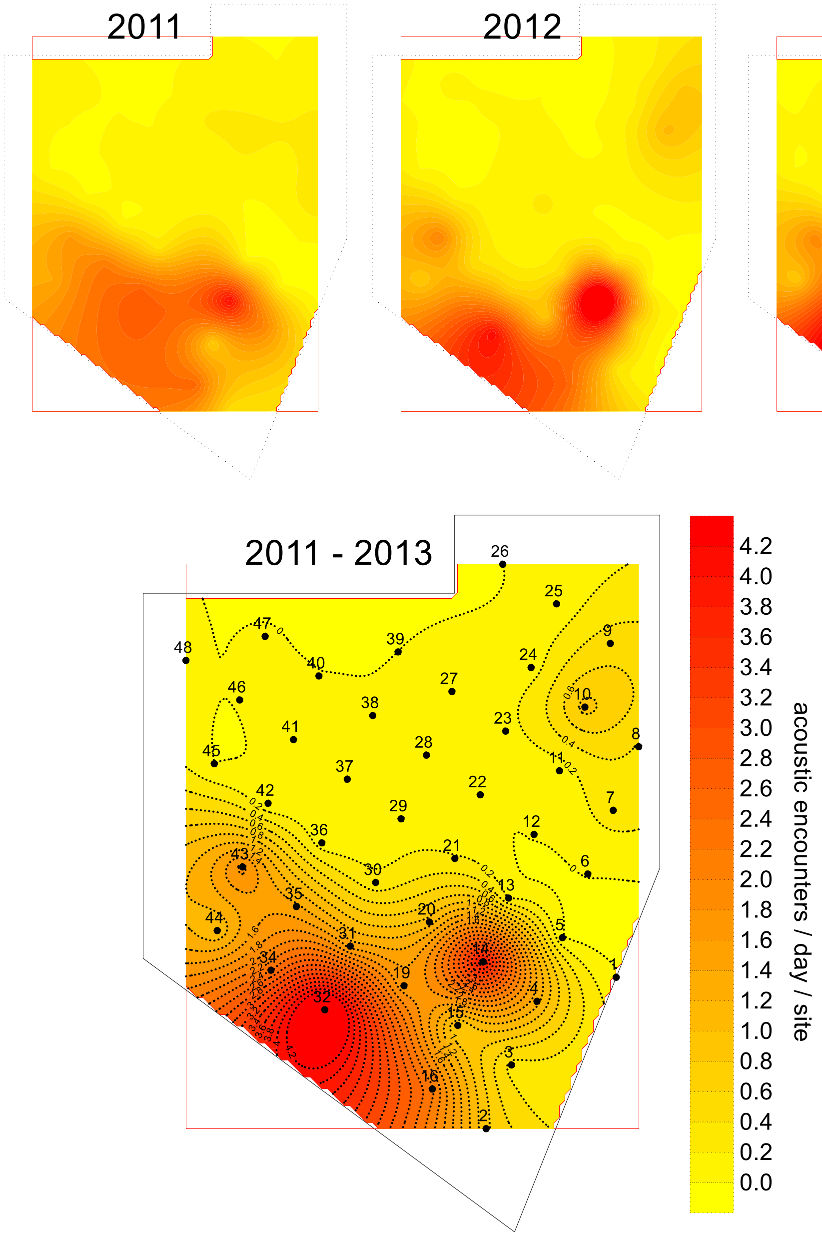


Figure 7. Acoustic encounter rate contour maps based on data for every sampling year and all data combined. The map for all data shows the position of the sampling sites. It is evident the heterogeneous distribution of the encounter rate and the highest acoustic activity around sites 14 and 32.

The optimization phase of ADMB (maximum likelihood estimation) was used to verify that models were numerically stable and correctly specified. Then the MCMC was run using zero as starting values for parameters except for dispersion parameter ***r***, which was started at a value of 0.2.

All models (equations 2, 3 and the polynomials in equation 4) were fitted using 500,000 MCMC simulations. Data for the simple model in Equation 2 only include days when all stations for the corresponding year have data, totaling 5,554 site-days.

Table below shows a description of the posterior distributions of parameter ***b*** for simple model and $\boldsymbol{b}_y$ for lineal and polynomial models. Figure 8 shows histograms of the same posteriors. For all models 95% credible intervals do not contain positive values for these parameters and the probability of a value lower than zero is greater than 0.99, indicating that a positive trend of encounter rate with time is unlikely.

Model	Min	Max	Average	Median	Std dev	Equal Tail Interval		Highest Density Interval		Credibility value <0
Simple	-0.3834	0.0334	-0.1771	-0.1770	0.0484	-0.2723	-0.0825	-0.2706	-0.0810	0.9999
Lineal	-0.2147	0.0465	-0.0851	-0.0851	0.0308	-0.1455	-0.0246	-0.1449	-0.0242	0.9971
Second degree	-0.2206	0.0491	-0.0903	-0.0903	0.0313	-0.1521	-0.0289	-0.1521	-0.0290	0.9980
Third degree	-0.2440	0.0295	-0.0932	-0.0930	0.0310	-0.1540	-0.0322	-0.1542	-0.0325	0.9988

The simple model estimates that average encounter rate in the Protection Refuge changed from around 0.76 encounters/day/site in 2011 to 0.53 in 2013, approximately a 16% annual decreasing.

Fixing latitude and longitude at the position of site 14, and tide difference at 2 meters, lineal, second degree and third degree models estimate negative annual changes of the average encounter rate of around 8.16, 8.64 and 8.90% respectively.

It is known that vaquita population decreased at an approximate annual rate of 7.6% between 1997 and 2008 (Gerrodette *et al.*, 2011). On the other hand, acoustic encounter rate decreased at an annual rate of approximately 8.34% (Jaramillo Legorreta, 2008), meaning that acoustic encounter rate could vary in direct proportion with abundance. Taking into account that since 2008 the Mexican Government initiated a program to reduce fishing effort that kills vaquitas, the adjustment of the simple model is unlikely as compared with the models including variation due to geographical position and tide in the sampling site.

Figure 9 shows output of the models as contours of encounter rate fixing the tide difference at 2 meters and year 2013. Comparing with data under these conditions, the third degree model appears to explain better the spatial variation of the encounter rate, although not locating precisely the sites with higher acoustic activity.

In conclusion, the modelling exercise after three sampling periods appear to have a high credibility that the acoustic encounter rate has been decreasing since 2011 at a rate higher than 8% per year, indicating the same fate for vaquita population level.

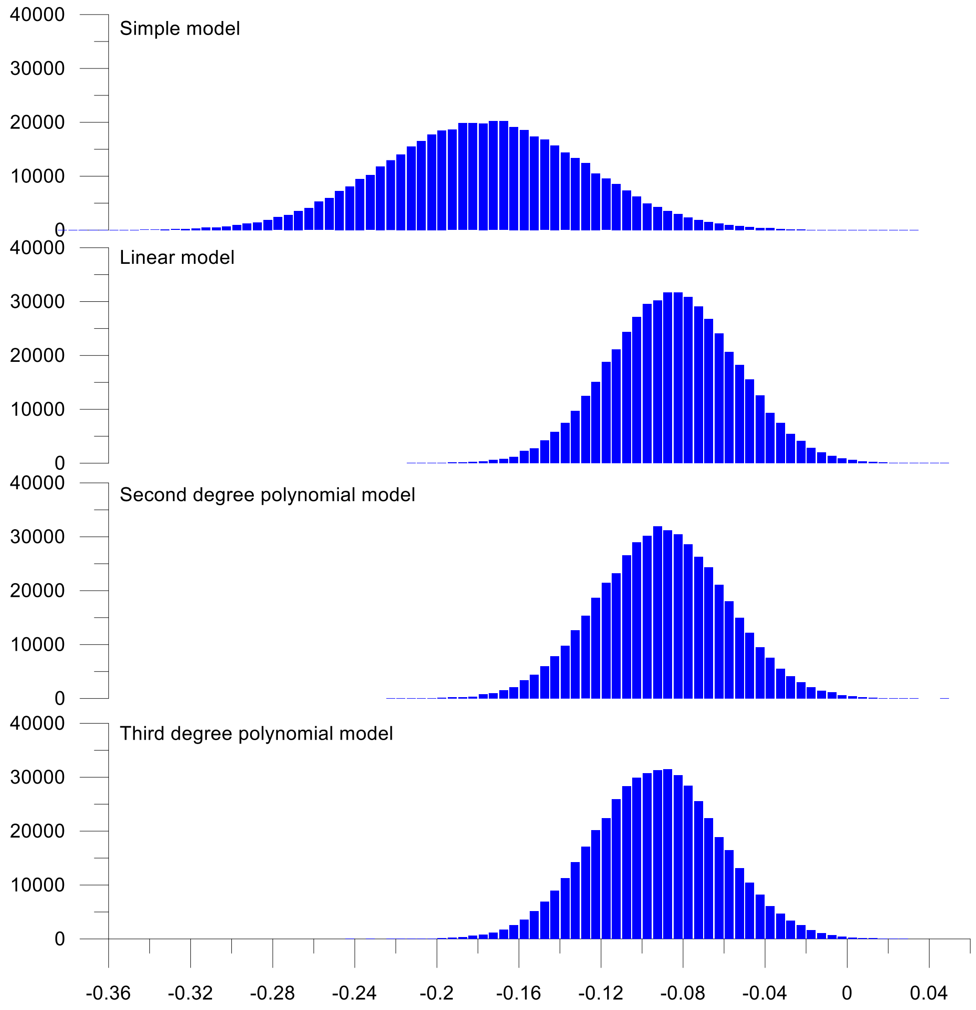


Figure 8. Posterior distributions of parameters ***b*** (top histogram) and $\boldsymbol{b_y}$ for the four models fitted. It is noted that simple model results in a more dispersed distribution. The other distributions are very alike, varying slightly in its mode.

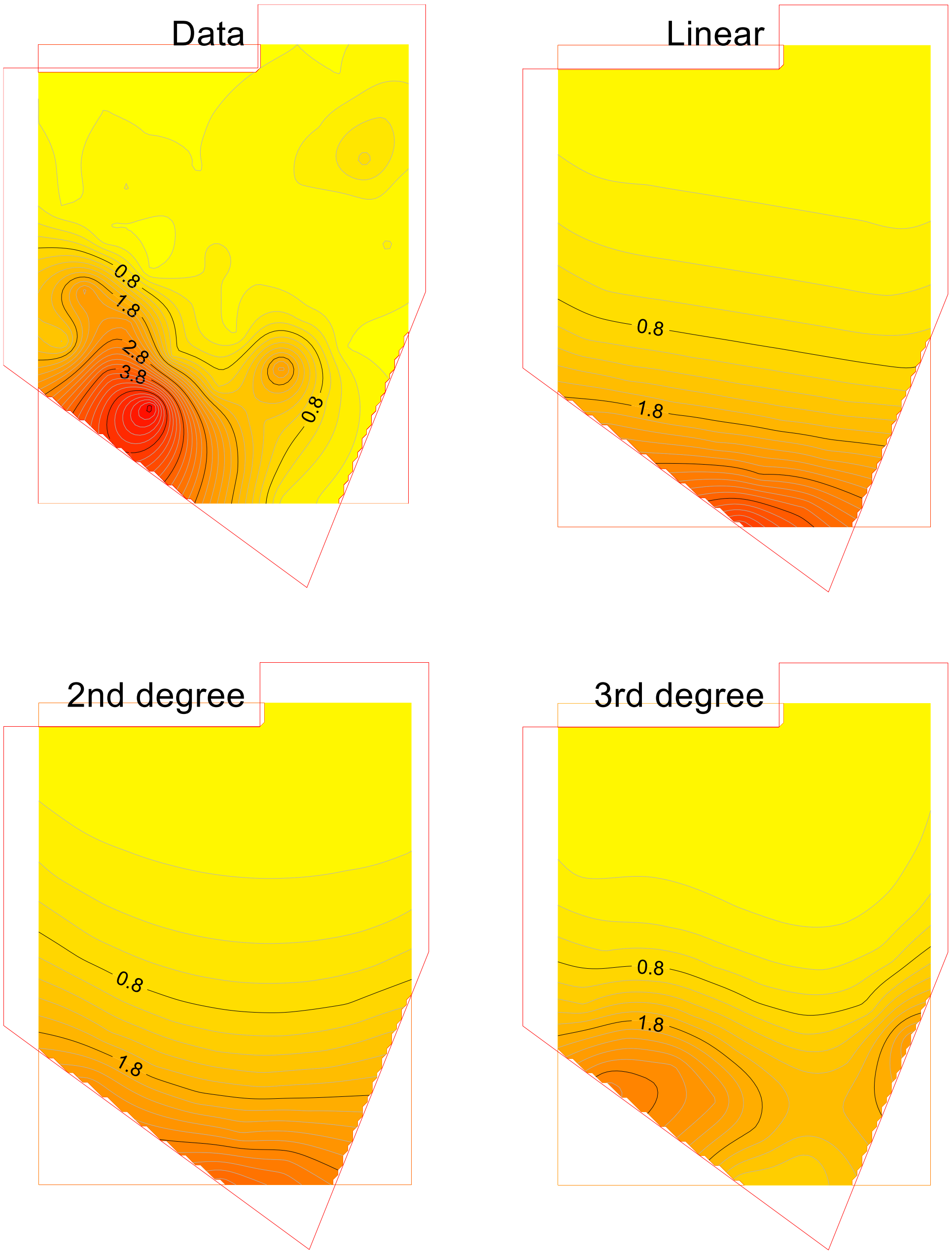


Figure 9. Acoustic encounter rate contour maps based on output of the models with space variation. It is evident that third degree model is the one better representing the map based on data. The output of models is obtained fixing for year 2013 and tide range 2 meters.

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Appendix 2. Assessment of false Vaquita detections in the output of GENENC, a generalised encounter classifier.

A visual inspection of acoustic data from the Vaquita monitoring program was carried out to test the accuracy of the Generalised Encounter Classifier (GENENC) and determine the rate at which false 'detection positive minutes', DPM, are likely to have been detected in error. GENENC is a classifier embodied in the CPOD.exe software. It can be applied to the data from all C-PODs.

Method

The data were examined in the UK by two analysts without any knowledge of the results obtained by the Mexican research term that had collected and also analysed the same data.

The CPOD.exe software was used to process the Vaquita files using the GENENC classifier, and filtered for narrow band high frequency, 'NBHF', click trains. The term 'trains' is synonymous with 'series' used in the report from the Mexican researchers.

All CP3 files that had one or more Vaquita DPMs were visually inspected and each false positive NBHF train marked by right clicking on the train and selecting "Mark train".

The GENENC software uses the presence of other trains that occurred in the recent past or near future as a factor for classifying a click train. Therefore false detections are more likely to occur within close proximity of true positives, because of this element of 'positive feedback'. Removing any single false train may not remove the minute from the DPM count as there may be other true NBHF trains within the same minute.

GENENC takes the output of the KERNO classifier that finds the trains and designates them as likely to be NBHF or not. GENENC assesses groups of likely NBHF trains that have no gap of more than 2 minutes. These GENENC encounters are not themselves used as a detection measure and are different from the encounters defined by the Mexican research term – those encounters have a 30 minute qualifying gap for the start of a new encounter.

The aim was to remove DPMs that did not have *any* true NBHF trains. The visual criteria used to assess the detected trains were based on the guidance in the cetacean validation guidelines (Validating cetacean detections.pdf). The main criteria were as follows:

To be accepted as a Vaquita encounter an encounter:

must show these features in the identified trains or train fragments seen within 2 minutes:

1. 95% or more of the clicks must have frequencies in the range 120-150kHz.
2. Some ICIs greater than 10ms.
3. Some click durations above 10cycles.
4. Most loud clicks (>100) are >10 cycles.

must not show these features:

1. Have a nearly constant ICI recurring through most of a minute or longer, due to clicks at Vaquita frequencies. This is the flat line seen on ICI displays of CP1 files, and it is due to SONARS.
2. An isolated train or pair of trains, (= where there are no 'good' train fragments, within 3 minutes, that fit (2-4) above) must be excluded if :
    a. It consists of only 1 or 2 weak trains (SPL < 30).
    b. There are only weak trains (SPL <50) with little shape to the SPL envelope or a ragged SPL profile. These could be 'WUTS' – weak unknown train sources.
    c. There are only fast trains (> 150/s = ICI < 7ms).
    d. If the trains are fast (ICI less than 5ms) and have <8 clicks.
    e. If the trains appear to be within multipath clusters. These could be chink spikes.
    f. Must not be a single train or sequence of trains with a very smooth rise in ICI (typically from 5ms or less) + little multipath + durations mostly below 10 cycles. These could be WUTS.
    g. Must not consist of loud short duration clicks as loud Vaquita clicks will be long.
3. No low frequencies (below 100kHz) that are either clustered with the multipath clusters of the detection (dolphins), or clustered with the train (mini-bursts). Low frequencies that occur at random are not a worry.
4. Trains close to dolphin encounters that show more than 20kHz range in their multipath clusters or do not show long weak clicks (the 'jump up, jump down' behaviour in the CPOD.exe graphical display).

Once all files had been assessed and false trains marked the NBHF DPMs were exported again and combined with the original list to see how many DPMs had been removed.

19.6 years of data consisting of 274 CPOD CP3 files were included, and were the whole data set available to us at the time.

Results

Of the 274 CP3 files 26 had Vaquita detections, so that trains in a total of 4.9 years of data were visually assessed.

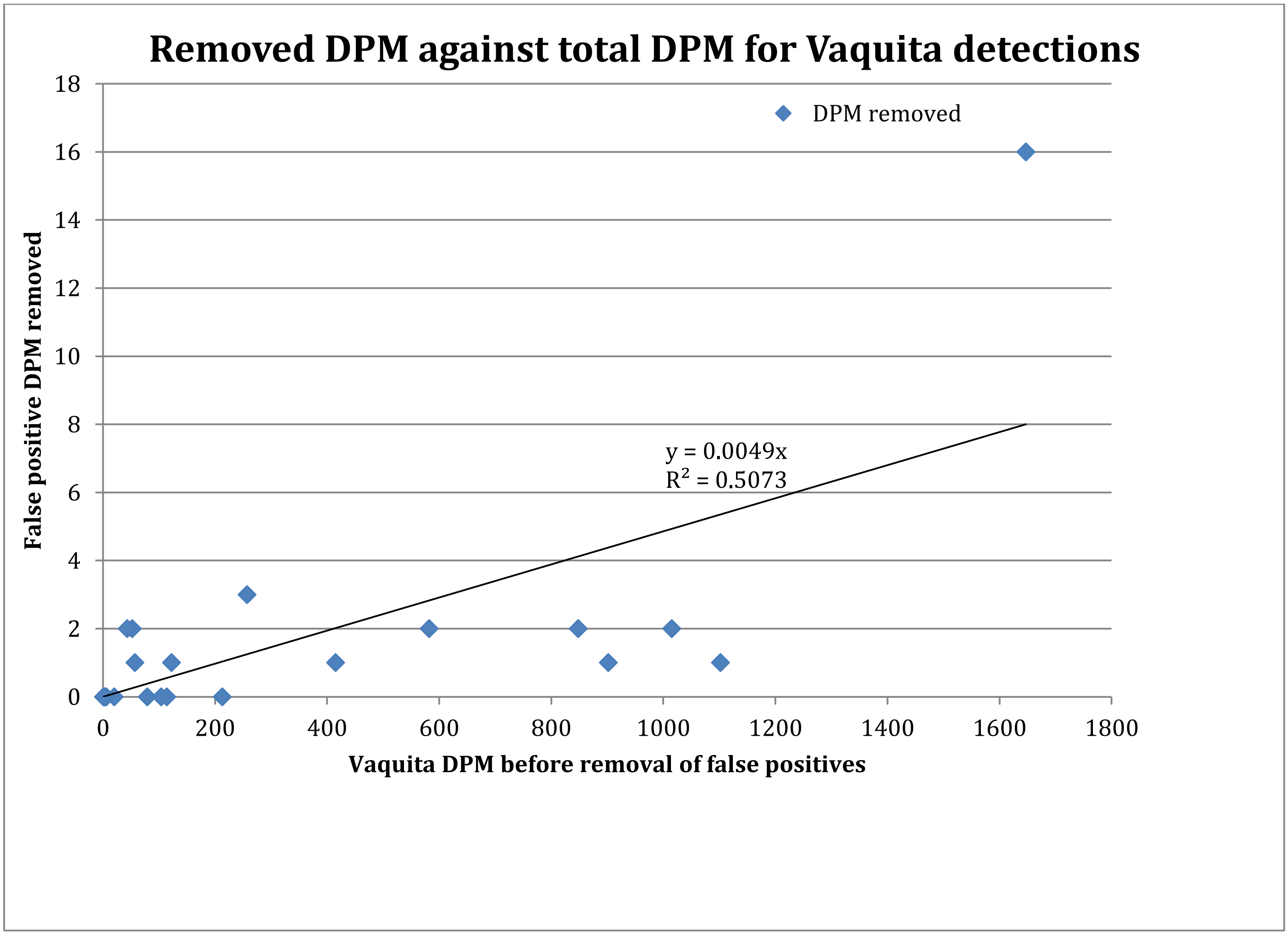
59 files had dolphin detections, a total of 7.6 years of data. All files that had Vaquita detections also had dolphin detections.

The table below shows the results for those files that had Vaquita detections from GENENC, ordered by Vaquita DPM count, with red highlighting for files in which false DPMs were identified.

File name *red indicates that DPM was reduced*	Vaquita detection positive minutes	Dolphin detection positive minutes	No of false Vaquita trains	Vaquita detection positive minutes after false trains removed	Vaquita detection positive minutes removed	Days On
G5 CPOD Sitio 14 2011 06 05 POD1308 file01.CP3	**1647**	**511**	**73**	**1631**	**16**	**72.04**
F6 CPOD Sitio 19 2011 06 05 POD1319 file01.CP3	**1102**	**208**	**14**	**1101**	**1**	**94.3**
D6 CPOD Sitio 35 2011 06 08 POD1502 file01.CP3	**1015**	**194**	**13**	**1013**	**2**	**86.7**
E6 CPOD Sitio 31 2011 06 02 POD1334 file01.CP3	**902**	**292**	**13**	**901**	**1**	**96.94**
G7 CPOD Sitio 16 2010 06 05 POD1313 file01.CP3	**848**	**294**	**15**	**846**	**2**	**81.75**
C6 CPOD Sitio 43 2011 06 09 POD1506 file01.CP3	**582**	**260**	**7**	**580**	**2**	**96.05**
F5 CPOD Sitio 20 2011 06 06 POD1320 file01.CP3	**415**	**296**	**5**	**414**	**1**	**73.68**
C7 CPOD Sitio 44 2011 06 09 POD1504 file01.CP3	**257**	**142**	**9**	**254**	**3**	**96.03**
H2 CPOD Sitio 7 2011 06 05 POD1300 file01.CP3	213	1990	2	213	**0**	87.73
G6 CPOD Sitio 15 2011 06 04 POD1309 file01.CP3	**122**	**1003**	**5**	**121**	**1**	**71.51**
F4 CPOD Sitio 21 2011 06 06 POD1331 file01.CP3	114	261	0	114	**0**	69.8
E2 CPOD Sitio 27 2011 06 01 POD1006 file01.CP3	104	500	0	104	**0**	102.77
H7 CPOD Sitio 2 2011 06 07 POD998 file01.CP3	79	602	1	79	**0**	59.8
E5 CPOD Sitio 30 2011 06 02 POD1337 file01.CP3	**57**	**162**	**1**	**56**	**1**	**64.38**
F2 CPOD Sitio 23 2011 06 06 POD1333 file01.CP3	**52**	**639**	**6**	**50**	**2**	**76.5**
G0 CPOD Sitio 9 2011 06 02 POD1301 file01.CP3	**43**	**189**	**6**	**41**	**2**	**76.61**
D4 CPOD Sitio 37 2011 06 09 POD1342 file01.CP3	20	75	1	20	**0**	57.2
E4 CPOD Sitio 29 2011 06 02 POD1336 file01.CP3	6	64	0	6	**0**	64.22
G2 CPOD Sitio 11 2011 06 05 POD1306 file01.CP3	4	1120	0	4	**0**	95.38
A4 CPOD Sitio 48 2011 06 09 POD1344 file01.CP3	3	166	0	3	**0**	52.58
G4 CPOD Sitio 13 2011 06 06	2	642	0	2	**0**	69.51

POD1315 file01.CP3						
E5 CPOD Sitio 30 2011 06 02 POD1337 file02.CP3	2	40	0	2	**0**	26.24
C4 CPOD Sitio 41 2011 06 09 POD1349 file01.CP3	2	7	0	2	**0**	23.39
I4 CPOD Sitio 1 2011 06 05 POD1316 file01.CP3	1	2668	0	1	**0**	81.63
E3 CPOD Sitio 28 2011 06 01 POD1009 file01.CP3	1	16	0	1	**0**	28.12
E4 CPOD Sitio 29 2011 06 02 POD1336 file02.CP3	1	13	0	1	**0**	9.68
Totals	7594	12354	171	7560	**34**	1814.54

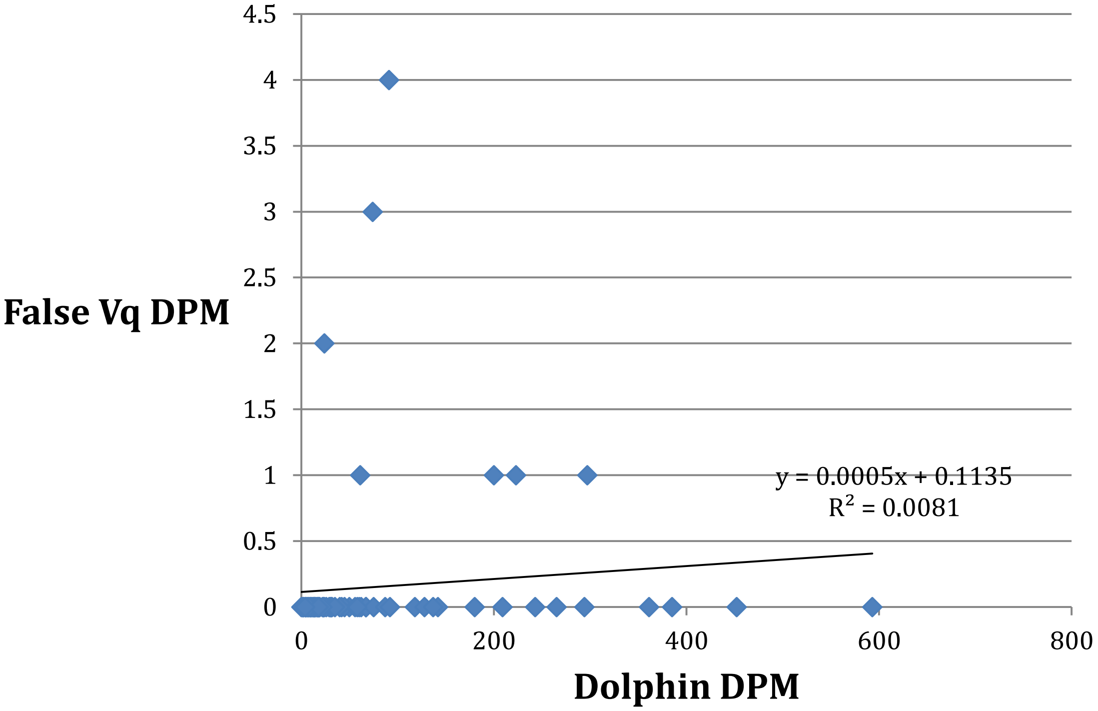
The higher incidence of false DPMs in files with many true DPMs is an expected consequence of using a classifier with positive feedback. The relationship is shown in the graph below:



False positive Vaquita detections plotted against total number of Vaquita detections before false trains were removed.

Dolphin presence may contribute to false positive Vaquita DPM, especially in the case of Common Dolphins, *Delphinus delphis,* that produce clicks in a frequency range that overlaps that of the Vaquita. Dolphin encounters are distinguished by the presence of shorter clicks of greater bandwidth occurring across a wider frequency range. In the Upper Gulf dolphin detections are more frequent than Vaquita detections, even in the highest density areas for Vaquita.

In the data examined the relationship between false Vaquita detections identified as from dolphins and the prevalence of dolphins is shown in the scatter graph below:



Detection and error rates:

True Vaquita DPM per year	**1521**
False Vaquita DPM per year	**7**
False Vaquita DPM as %True Vaquita DPM	0.4%
False Vaquita DPM as %Dolphin DPM	0.3%

Discussion

Table 2 shows that around 0.4% of detection positive minutes are false in this dataset.

None of the low Vaquita DPM count files contain false positives, indicating that Vaquita detections generate the very low level of false positives as a result of the positive feedback element in GENENC. This is a benign source of false positives as it does little other than increase the reported Vaquita detection rate by a very small fraction -approximately 0.4% and can safely be ignored as it will not affect trends or distributions. False positives from other sources could affect both trends and distribution, but are at a very low level.

Other issues:

False negatives were not looked for in the (raw) CP1 data. It is possible to do this by filtering the raw data to show only clicks with a SPL >30, kHz 125-150, duration > 15cycles in minutes with more than 8 such clicks. This does pick up some Vaquita detections that are not otherwise found. However, it would not improve the detection of a trend in the population unless the overall number of detections was very low, and would require further validation.

WUTS - weak unknown train sources. Such train sources have been seen in earlier T-POD data, and in C-POD data from the Upper Gulf. There appear to be few WUTS in this dataset but as their origin is unknown, and is thought to be biological, there is a possibility of large changes in incidence. WUTS indicate that some visual oversight of the data should be maintained, as the performance of GENENC where WUTS are prevalent is not well known.

Dolphins - false negatives - GENENC can only classify one species per encounter. So a high prevalence of dolphins would obscure some Vaquita detections. This circumstance is easily identified as dolphin detections can be obtained from the C-POD data. In the 2011-2013 data there is no increase in dolphins.

Noise levels will inevitably have some impact on the detectability of Vaquita and are also likely to affect their distribution. If noise levels showed progressive change this would require specific assessment as it is not demonstrated by GENENC. The raw C-POD data does provide information on noise levels.

Conclusion

Visual inspection and assessment shows that false positive Vaquita DPM is 0.4% of total Vaquita DPM for this dataset.

Most of the trains that have been found to be false positive Vaquita detections were detected by the GENENC algorithm due to their proximity to true positives within the same encounter and removing them would not alter the trend in detection positive minutes.

GENENC should be a stable reference tool to detect drift or bias in the performance of visual analysts but does not remove the need for visual oversight of the data and detections.

Appendix 3. **Model using categorical variables instead of geographical positions to account for spatial structure of encounter rate**

In this model latitude and longitude were replaced by a set of dummy variables constructed from the sampling sites. Only sites with at least 60 sampling days per year, and at least two years of data, were included in the data set. Hence, sites 3, 8, 12, 17, 18, 33 and 34 are not in the set, which results in a set of 41 dummy variables.

Every dummy variable takes a value of 1 when data corresponds to that site and the reminder dummy variables take a value of zero. In addition the model includes the year and tide information as in the models explained before:

$$\bar{y} = e^{b_0+(b_y y)+(b_t t)+(b_{s1}s1)+\cdots+(b_{s48}s48)}$$

Where b_{sn} are the coefficients for every sampling site *sn*, being n the sampling site number as in Figure 3.

The model was fitted using also ADMB. Its optimization routine was used to estimate point values and standard deviations of the coefficients of the model.

Parameter	Point	s.d.	Parameter	Point	s.d.	Parameter	Point	s.d.
b_0	-2.850	9003.0000	bs04	3.455	9003.0000	bs23	1.262	9003.0000
b_y	-0.222	0.0283	bs44	3.234	9003.0000	bs38	-1.179	9003.0000
b_t	-0.044	0.0147	bs10	3.225	9003.0000	bs28	-1.179	9003.0000
r	1.008	0.0536	bs20	3.218	9003.0000	bs47	-1.141	9003.0000
bs39	-15.065	9029.1000	bs02	3.108	9003.0000	bs37	1.076	9003.0000
bs45	-14.509	9017.3000	bs15	2.985	9003.0000	bs27	1.026	9003.0000
bs26	-14.062	9015.3000	bs09	2.585	9003.0000	bs24	0.981	9003.0000
bs05	-13.903	9009.0000	bs40	-2.385	9003.0000	bs48	-0.964	9003.0000
bs32	5.044	9003.0000	bs07	2.063	9003.0000	bs06	-0.884	9003.0000
bs14	4.639	9003.0000	bs46	-1.961	9003.0000	bs22	-0.831	9003.0000
bs16	4.057	9003.0000	bs30	1.919	9003.0000	bs36	0.754	9003.0000
bs43	3.887	9003.0000	bs21	1.685	9003.0000	bs11	0.680	9003.0000
bs19	3.588	9003.0000	bs13	1.447	9003.0000	bs01	-0.440	9003.0000
bs35	3.556	9003.0000	bs41	1.414	9003.0000	bs42	-0.440	9003.0000
bs31	3.535	9003.0000	bs29	1.399	9003.0000	bs25	0.273	9003.0000

The point estimate of parameter b_y, coefficient of the year variable, agrees with previous models estimating a negative trend with year. However, its magnitude is the highest of any of the models explained before. Its standard deviation, on contrary, is the lowest.

Parameters for dummy variables are listed after parameters for intercept, year, tide and the dispersion parameter of the negative binomial distribution supposed for encounter rate data. They are sorted from highest to lowest absolute values for point estimate. The highest negative values correspond to low density sites in the north (Figure 7) and the highest positive ones to the sites with the highest encounter rates (sites 14 and 32). A concern with this model arises from the extremely high standard deviations estimated for site parameters, which also affects the intercept. High correlations between dummy variables appear to affect the model, which indicates the need to use an alternative approach, as group by lines of sites or zones inside the study area.

Appendix 4. R code used to model trends in vaquita abundance from CPOD data and to produce Table 1 and Figures 10-12.

```
# This program models vaquita relative abundance
#   as thin plate spline fits to Lat & Long.
#   and outputs gridded results for the study area.

# This works with R version 2.12.0 and 3.0.1, but the plot export
# only works as bitmap save.
# The plots look best using RStudio with this version of R

  library('mgcv')
  library(maps)
  library(sp)
  library(maptools)
  library(raster)

# Read CSV files with detection distances and other variables
  setwd("e:/")
  VaqPodData= read.csv("Vaquita data.csv")     # all delphinid species

#  VaqPodData= VaqPodData[VaqPodData$Year!=2011,]  #eliminate first year
#  VaqPodData= VaqPodData[VaqPodData$Year!=2013,]  #eliminate last year

  summary(VaqPodData)
  Lat=   VaqPodData$latitude
  Long=  VaqPodData$longitude
  ER=    VaqPodData$Encounters
  DPM=   VaqPodData$DPM
  Site=  as.factor(VaqPodData$Site)
  nSite= VaqPodData$Site
  Year=  VaqPodData$Year
  CatYear=  as.factor(VaqPodData$Year)
  Year2013TF= (VaqPodData$Year==2013)
  Tide=  VaqPodData$tide

# Calculate raw trends in mean values of ER and DPM
  1-mean(ER[Year==2012])/mean(ER[Year==2011])
  1-mean(ER[Year==2013])/mean(ER[Year==2012])

  1-mean(DPM[Year==2012])/mean(DPM[Year==2011])
  1-mean(DPM[Year==2013])/mean(DPM[Year==2012])

# Conduct GAM EncounterRate analysis using mgcv

  VaqPodGam_ER_year= gam(formula= ER ~ Year, family=negbin(theta=c(1.0)), gamma=1.4)
  summary(VaqPodGam_ER_year)

  VaqPodGam_ER_year_Tide= gam(formula= ER ~ Year + Tide, family=negbin(theta=c(1.0)), gamma=1.4)
  summary(VaqPodGam_ER_year_Tide)

  VaqPodGam_ER_CatYear= gam(formula= ER ~ CatYear, family=negbin(theta=c(1)), gamma=1.4)
  summary(VaqPodGam_ER_CatYear)

  VaqPodGam_ER_year_Lat_Long= gam(formula= ER ~ s(Year,k=2) + s(Long,Lat,bs='tp'),
family=negbin(theta=c(1)), gamma=1.4)
  summary(VaqPodGam_ER_year_Lat_Long)
  plot(VaqPodGam_ER_year_Lat_Long,se=FALSE,shade=TRUE,too.far=0.1)
```

```
 VaqPodGam_ER_year_PolyLatLong_Tide= gam(formula= ER ~ Year + poly(Lat,3) + poly(Long,3) + Tide,
family=negbin(theta=c(1),link = "log"), gamma=1.4)
 summary(VaqPodGam_ER_year_PolyLatLong_Tide)

 VaqPodGam_ER_site_year= gam(formula= ER ~ Site + Year, family=negbin(theta=c(1)), gamma=1.4)
 summary(VaqPodGam_ER_site_year)

 # Conduct GAM DPM analysis using mgcv

 VaqPodGam_DPM_year= gam(formula= DPM ~ Year, family=negbin(theta=c(1,5)), gamma=1.4)
 summary(VaqPodGam_DPM_year)

 VaqPodGam_DPM_year_Tide= gam(formula= DPM ~ Year + Tide, family=negbin(theta=c(1,5)), gamma=1.4)
 summary(VaqPodGam_DPM_year_Tide)

 VaqPodGam_DPM_CatYear= gam(formula= DPM ~ CatYear, family=negbin(theta=c(1)), gamma=1.4)
 summary(VaqPodGam_DPM_CatYear)

 VaqPodGam_DPM_year_Lat_Long= gam(formula= DPM ~ s(Year,k=2) + s(Long,Lat,bs='tp'),
family=negbin(theta=c(1),link = "log"), gamma=1.4)
 summary(VaqPodGam_DPM_year_Lat_Long)
 plot(VaqPodGam_DPM_year_Lat_Long,se=FALSE,shade=TRUE,too.far=0.1)

 VaqPodGam_DPM_year_PolyLatLong_Tide= gam(formula= DPM ~ Year + poly(Lat,3) + poly(Long,3) + Tide,
family=negbin(theta=c(1),link = "log"), gamma=1.4)
 summary(VaqPodGam_DPM_year_PolyLatLong_Tide)

 VaqPodGam_DPM_site_year= gam(formula= DPM ~ Site + Year, family=negbin(theta=c(1)), gamma=1.4)
 summary(VaqPodGam_DPM_site_year)


# Estimate ratios of mean fitted Values in successive years.

 mean2011= mean(VaqPodGam_DPM_year_Lat_Long$fitted.values[Year==2011 & nSite==30])
 mean2012= mean(VaqPodGam_DPM_year_Lat_Long$fitted.values[Year==2012 & nSite==30])
 mean2013= mean(VaqPodGam_DPM_year_Lat_Long$fitted.values[Year==2013 & nSite==30])
 mean2012/mean2011
 mean2013/mean2012

# Create Prediction Data Frame over defined study area
 minLat= 30.9
 maxLat= 31.4
 minLong= -114.75
 maxLong=  -114.40
 PredLat= minLat
 PredLong= minLong
 for (iLat in seq(minLat,maxLat,by=0.005)) {
   for (iLong in seq(minLong,maxLong,by=0.005)) {
     PredLat= c(PredLat,iLat)
     PredLong= c(PredLong,iLong)
   }
 }


 PredictData2011= data.frame(Lat=PredLat,Long=PredLong,Year=2011,nSite=32)
 DPM_Prediction2011= predict.gam(VaqPodGam_DPM_year_Lat_Long,newdata= PredictData2011)
 ER_Prediction2011= predict.gam(VaqPodGam_ER_year_Lat_Long,newdata= PredictData2011)

 PredictData2012= data.frame(Lat=PredLat,Long=PredLong,Year=2012,nSite=32)
 DPM_Prediction2012= predict.gam(VaqPodGam_DPM_year_Lat_Long,newdata= PredictData2012)
 ER_Prediction2012= predict.gam(VaqPodGam_ER_year_Lat_Long,newdata= PredictData2012)
```

```
  DPM_Prediction2011[1:10]
  DPM_Prediction2012[1:10]
#NOTE, predictions are additive, exp(predictions) are multiplicative
  1-exp(DPM_Prediction2012[1:10])/exp(DPM_Prediction2011[1:10])
  (DPM_Prediction2012[1:10]-DPM_Prediction2011[1:10])


# Read study area boundary (see code below to create study area boundary)
  StudyArea= readShapePoly(fn="StudyBoundary")

#DPM Geographic Smooth Plots
# Create raster map of predicted values
  Predict.dataframe= data.frame(PredLong,PredLat,DPM_Prediction2012)
  Predict.raster= rasterFromXYZ(Predict.dataframe)
# Mask areas outside of study area
  Predict.raster= mask(x=Predict.raster,mask=StudyArea)
# plot raster
  par(mfrow=c(1,1))
  plot(Predict.raster, col=rainbow(8))
  title("Fitted DPM Model")
#  plot(Long,Lat,add=TRUE)
#  plot(Predict.raster,add=TRUE, col=gray.colors(8,start=0.1,end=0.8))

#ER Geographic Smooth Plots
  # Create raster map of predicted values
  Predict.dataframe= data.frame(PredLong,PredLat,ER_Prediction2012)
  Predict.raster= rasterFromXYZ(Predict.dataframe)
  # Mask areas outside of study area
  Predict.raster= mask(x=Predict.raster,mask=StudyArea)
  # plot raster
  par(mfrow=c(1,1))
  plot(Predict.raster, col=rainbow(8))
  title("Fitted ER Model")
#  plot(Long,Lat,add=TRUE)
#  plot(Predict.raster,add=TRUE, col=gray.colors(8,start=0.1,end=0.8))



# Output gridded data of smoothed, modeled Beauf, Lat  Long
#    Average.Beaufort= data.frame(endLat,minusEndLong,Prediction)
#    names(Average.Beaufort)= c("Latitude","Longitude","Avg. Beaufort")
#    write.csv(Average.Beaufort,"C:\\Users\\Jay\\abund\\Inferring
Gzero\\BeaufortGeoSmooth.dat",row.names=FALSE)
#    rm(endLat,minusEndLong,Prediction,PredictData)


# Create a study area boundary shape file (only needs to be done once)
# interactive definition of study polygon (USE R, not R studio)
# left click to form polygon then right click and chose stop
   plot(Long,Lat)
   BoundPoly= drawPoly()
   BoundPolyDF= SpatialPolygonsDataFrame(Sr=BoundPoly,data=data.frame("A"))
   writePolyShape(BoundPolyDF,fn="StudyBoundary")
```

Report on Vaquita Rate of Change Between 2011 and 2013 Using Passive Acoustic Data
by the Expert Panel on Spatial Models

June 24-26, 2014
Meeting held at Southwest Fisheries Science Center, La Jolla, CA, USA

Participants:
- Armando Jaramillo-Legorreta*
- Lorenzo Rojas-Bracho
- Jay VerHoef*
- Jeff Moore*
- Len Thomas*
- Jay Barlow*
- Justin Cooke*
- Tim Gerrodette
- Barbara Taylor

*Analysts comprising the Expert Panel

Executive Summary

After reviewing preliminary analysis results from the first three seasons (2011-2013) of the acoustic monitoring program, the Vaquita Acoustic Monitoring Steering Committee recommended that a panel of analytical experts be convened to estimate the trends in vaquita acoustic detections during this period. The Expert Panel[1], which met from the 24-26th of June 2014, analyzed these data and estimated a 33% decline in vaquita acoustic activity in the sampled area from 2011 to 2013. This rate of decline, 18.5% per year (95% Bayesian Confidence Interval -0.46 – +0.19 per year), is greater than any previously reported for vaquita. The Panel found a high probability that the acoustic activity has declined (prob. = 0.88) with the clear majority of evidence indicating a rate of decline greater than 10% per year (prob. = 0.75). Other factors, like changes in fishing effort, should be considered for an appropriate measure of uncertainty in trends in vaquita abundance.

The Panel considered the monitoring design to be sound but analyses were complicated by the loss of some monitoring devices (CPODs) in the first year (2011) and low numbers of recording days for numerous CPOD devices in 2013. Several analyses were developed to account for the uneven sampling; all indicated substantial declines similar to the agreed estimate of 18.5% per year. Although the Panel agreed that year-to-year variation in the proportion of vaquitas present within the monitoring area could not be accounted for with this short time series (with only half of the intended monitoring period completed), the chances that this critically endangered species has continued to decline at a high rate are great.

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[1] The panel consisted of 6 modeling experts including two from the Vaquita Acoustic Monitoring Steering Committee (Jaramillo and Barlow) and four globally recognized

Introduction

In 2011, the passive acoustic monitoring program for vaquitas (*Phocoena sinus*) began the first full season of data collection. In April 2014, the Vaquita Acoustic Monitoring Steering Committee (SC) met to review data from the first 3 seasons of data (2011, 2012, 2013). Preliminary analysis suggested a dramatic decline in the vaquita population between 2011 and 2013 (Jaramillo-Legorreta et al. 2014). However, because the realized sampling effort was uneven across the sampling grid and over each sampling season, analysis of the data was not simple. Therefore, the SC recommended that a panel of experts with specific skills in spatial or trend modeling be convened to provide the best scientific analysis of trends in abundance of vaquita acoustic detections in a timeframe needed to manage this critically endangered species. The expert Panel was formed and met at the Southwest Fisheries Science Center in La Jolla, California, on June 24-26, 2014. This document reports the findings of the meeting.

Background

The vaquita is a small species of porpoise found only in the northern Gulf of California, Mexico (Figure 1). It is subject to unsustainable bycatch in gillnet fisheries throughout its small range and, consequently, is classified as critically endangered by the International Conservation Union (IUCN).Although they are known to occur in waters 10-50 m deep, their distribution within the shallow water area is poorly characterized. The vaquita detections shown in Figure 1 are not fully representative of distribution in shallow water areas because most sightings are from a ship that cannot navigate shallow waters (see tracklines in Figure 1). The polygon within the figure is the Vaquita Refuge, which was agreed to in September 2005 (Protection Program published on December 2005) and within which no commercial fishing is allowed (no matter what fishing gear is used, even hooks). About half of vaquitas are estimated to be in the Refuge at any given time (Gerrodette and Rojas-Bracho 2011). Surveys in different years (1997 and 2008; Jaramillo-Legorreta *et al.*, 1999; Gerrodette *et al.*, 2011) suggest that for the months of surveys (most from August through November) the distribution of vaquitas is remarkably constant. Within the Refuge, vaquitas are unevenly distributed.

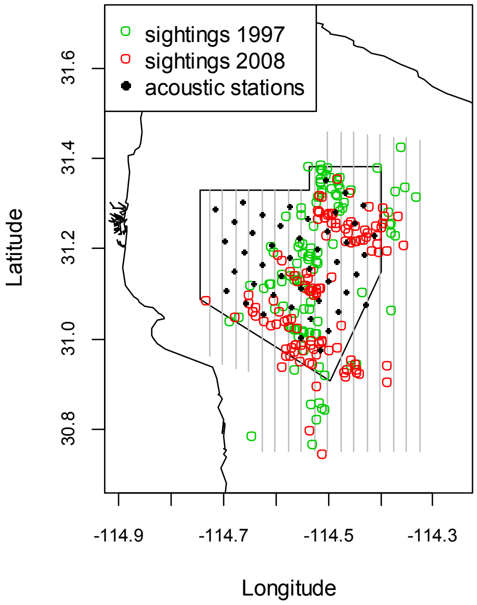

Figure 1. Visual detections (red and green circles) from two major ship surveys (in 1997 and 2008), with the survey track lines shown as light gray lines. The C-POD locations (deployed regularly since 2011) are shown as black dots and the Vaquita Refuge is outlined in black.

Because of the expense and imprecision of visual surveys (Jaramillo Legorreta, 2008; Rojas-Bracho *et al.*,2010), Jaramillo pioneered acoustic monitoring for vaquitas starting in 1997. Acoustic monitoring is possible because porpoises use echolocation to find their prey in the turbid waters of the northern Gulf of California. Jaramillo deployed boat-based acoustic detectors at fixed listening stations located throughout the range of vaquitas to examine the change in acoustic encounters over a period of 11 years (1997-2008) and showed a marked decline of 7.6%/year for a total decline of 58% (Jaramillo-Legorreta 2008). By the end of this study most stations recorded no vaquita acoustic activity and it became obvious that the level of acoustic monitoring effort achieved during the initial years of research were no longer sufficient to monitor vaquita activity accurately.

Thus, in 2008 several types of bottom-mounted passive acoustic devices, which are capable of recording autonomously for several months, were tested to increase the acoustic sampling effort for the dwindling numbers of vaquitas. A device called the CPOD had the best performance (Rojas-Bracho et al. 2010). The CPOD records characteristics of acoustic activity continuously over a period of several months. A Steering Committee (SC) was formed to design an acoustic monitoring project capable of detecting a ≥4%/year increase over a 5 year period (which would include 6 monitoring seasons). The SC created a grid design using 48 bottom-mounted CPODs deployed inside the Refuge for about 90 days each year. The original monitoring design also included CPODs located on Refuge perimeter buoys, but these CPODs were nearly all lost due to entanglement with fishing gear and likely active removal. A feasibility project was conducted using bottom-mounted CPODs just outside the southwestern boundaries of the Refuge but 6 of 8 were lost indicating that this area is still not possible to monitor with fixed CPODs (Jaramillo-Legorreta 2014).

After 2 years of initial testing and development, the acoustic monitoring program began its' first full season in 2011. The deployment and recovery of the bottom-mounted grid of CPODs was very successful over the first 3 seasons. However, the number of days recorded by individual CPODS differed because some CPODs were lost and never recovered, others shut off early within a season, and some filled their memory with background noise prior to retrieval. Figure 2 illustrates the achieved acoustic monitoring effort (i.e., days of acoustic monitoring per C-POD station) for the first 3 years.

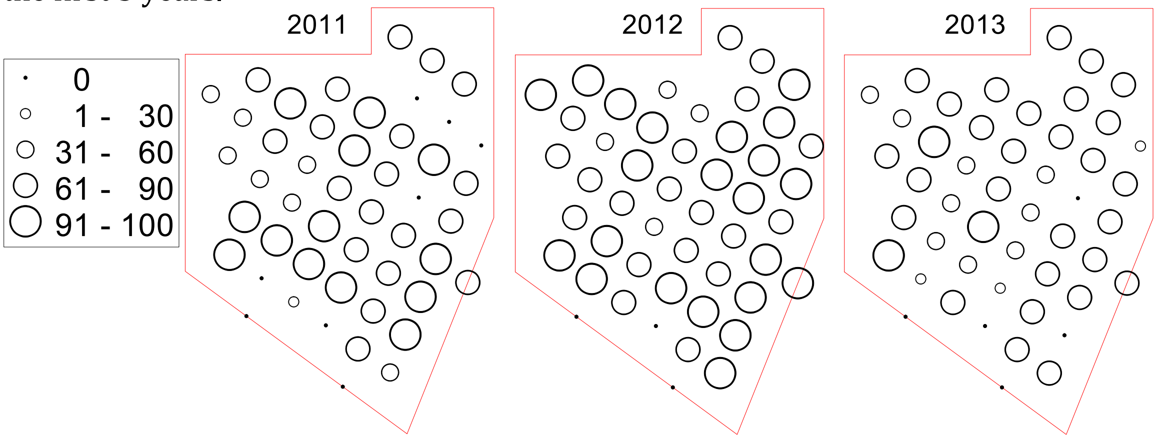

Figure 2. Locations of sampling sites, with number of days of monitoring effort indicated by circle size.

Effort also differed seasonally within year. CPODs were deployed later in 2012 and 2013 than in 2011 to avoid CPOD loss resulting from fishing activities (Figure 3), and deployment date now depends on information from aerial surveys that illegal fishing activities within the Refuge have largely ceased.

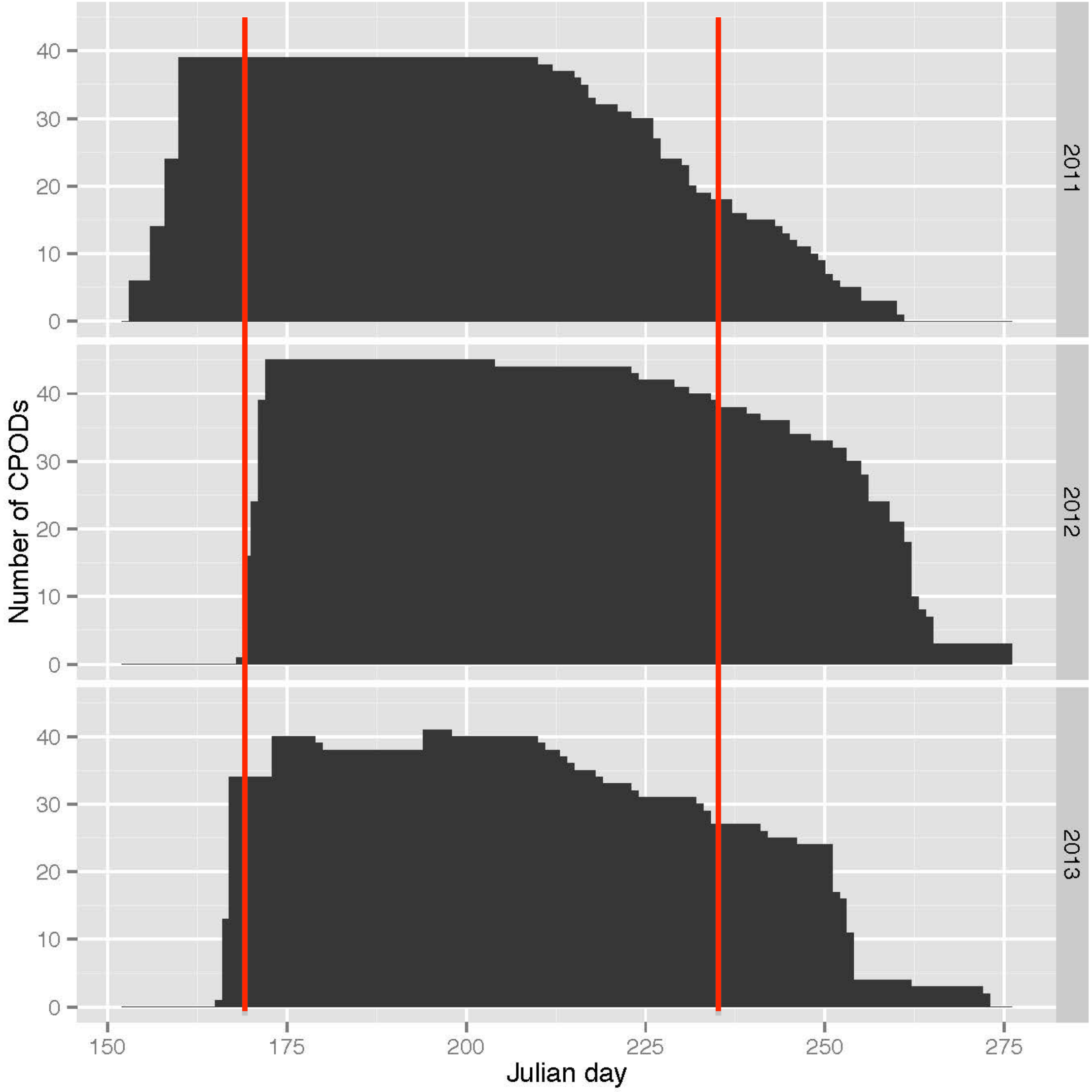

Figure 3. Effort by Julian day for each year. Julian dates shown run from May 30 (150) to October 2 (275). Vertical red lines enclose the core sampling period (from Julian day 170-231, June 19 to August 18, where ≥ 50% of the CPODs were operating in all years (discussed below). Julian dates actually vary slightly because of leap year.

Estimating the change in numbers of vaquita acoustic detections from 2011 to 2013 required an analytical treatment that accounts for the spatial and temporal differences in sampling within and between years, as shown in Figures 2 and 3. Conceptually, the analytical task is to best approximate the results that would have been obtained if all the circles in the grid shown in Figure 2 of were of equal size each year (same level of CPOD effort at all stations in all years). To do that, the Panel needed to consider all the factors that may make effort unequal and decide the best method of inference for stations that were un- or under-represented. In addition, the Panel needed to consider other factors besides differences in vaquita abundance or activity that may have caused differences in detections between years.

The simplest approach to measuring trends in vaquita clicks from C-POD data is to calculate the ratio of total clicks counted in 2011 to the total number in 2013. However, this approach does not account for C-PODs that were lost or C-PODs that were not functional for the entire core sampling period. If C-PODs were lost predominately in high-density areas (which appears to be the case in 2011), this simple approach would produce biased estimates of trends. Likewise, if some sites received less effort, the total counts should be standardized to the number of days sampled, to avoid bias. To avoid both of these problems, analysis can be limited to data from sites that were sampled in all three years, and the mean number of clicks per day of sampling effort could be calculated for all these common sites. This direct-count method was used to produce estimates for comparison with other, better methods, which use more of the data (including data from sites that were only sampled in one or two years) and provide statistical estimates of uncertainty about the true trend given the data. The direct-count method does not make any estimate of certainty about the true trend but rather relies on an assumption that the data perfectly represent the true trend.

In contrast with the direct-count method, the Panel conducted statistical analyses that use spatial and temporal information within the dataset to estimate the probability that the acoustic data could have been observed by chance alone (noting that the data are a sample rather than perfect measurement of what we want to estimate) and to obtain a better estimate of trends that reflects uncertainty about the true trend for the population. The expert panel was directed to find the best method of statistical analysis to account for uncertainty and to make optimal use of all the available data.

Considerations from the Expert Panel

The primary objective of the Panel was to estimate the annual mean rate of change in numbers of vaquita acoustic detections from 2011 to 2013 together with any uncertainties in that rate. A necessary assumption for analysis was that the annual rate of change in acoustic detections is a reasonable proxy for the rate of change in vaquita numbers. There are several important factors to keep in mind when interpreting the trend estimates from these first 3 years of acoustic detections.

First, if the monitoring grid covered the entire distribution of vaquitas, then inference about change in total vaquita population abundance would just depend on the assumption that click behavior remained the same through the time period (i.e., more recorded clicks would imply more vaquitas, not just more vocalizing, in the sampling area). Click behavior was investigated and there was no evidence of a change in clicks-per-vaquita in different years (see below). Additionally, there are data from past efforts covering the full range of vaquitas that support the assumption that acoustic detections and numbers of vaquitas decline at the same rate. For example, between 1997 and 2008 visual surveys and acoustic monitoring resulted in identical estimates of rate of change with a decline of 7.6%/year (Gerrodette et al. 2011, Jaramillo-Legoretta 2008). Therefore, the assumption that the number of recorded clicks is related to the level of use in the sampling area was judged to be reasonable.

Second, intense fishing outside the Refuge, even in the low summer fishing season, precludes using bottom-mounted CPODs outside the Refuge. Because the grid covers only a proportion of the vaquitas range, the other important assumption is that the proportion of vaquitas using the monitoring area over the summer period is the same each year. Over the 6-sampling seasons that the monitoring program was designed to cover, the changes in proportion in the Refuge would be expected to vary somewhat from year to year but not in any systematic way that would bias the rate-of-change estimate. However, with just three seasons of data (two periods of change), there is greater uncertainty about how much of the estimated annual change reflects change in overall population abundance vs. differences in the proportion of population using the sampling area each year. The length of the sampling period within a year mitigated this variability somewhat, but the Panel recognized these limitations to inference from the analysis. Additional years of data will allow this issue to be addressed analytically.

Panelists agreed that the design of the monitoring program, which has systematic spatial coverage throughout the core of the Vaquita Refuge (and central to the distribution of the species) over a period of several months each year, was good, and that the analysis should rely primarily on this good design rather than on model-based spatial or temporal extrapolation to unsampled areas. The Panel carried out some basic descriptive analyses to consider factors other than a change in the number of vaquitas that might affect the number of acoustic detections observed.

Time of day: Because CPODs record data 24 hours per day and only whole days are used in the analysis, the sampling design is balanced with respect to time of day. **The Panel agreed that analysis could proceed without accounting for the influence of time of day on the data.**

Tide: The northern Gulf has a tidal range of over 10m (30 feet), which has potential to influence vaquita behavior and therefore acoustic detections. Therefore, the sampling of tidal states should be similar in different years if analyses are conducted without accounting for sampling of tidal states. Jaramillo stratified the data into different tidal states. The tidal regime in the Upper Gulf of California is semidiurnal (two high and two low tides per day) and a cycle of spring-neap tides last approximately 15 days. Instead of using tide height as presented in tide tables, Jaramillo calculated the vertical speed of tide per hour as an index of tide current (using the tide height at the current hour minus the tide height at the previous hour). The absolute value was used, which does not distinguish between flood or ebb tides.Coverage of tidal states was similar between years (Table 1, 0.1 meters/hour intervals). A Kruskal-Wallis ANOVA by ranks indicated that the samples of every year originated from the same distribution, $H_{d.f\,2,\,n=4464}$=3.285, p=0.1934. A median test gives similar non-significant results (Chi-squared=1.2, d.f.=2, p=0.5491). **The Panel agreed that analysis could proceed without accounting for the influence of tides on the data.**

Table 1. Number of hours sampled in eighteen vertical tide speed intervals for each sampling year period (2011-2013).

Tide speed interval		2011	2012	2013
≥ 0.0	≤ 0.1	151	150	130
> 0.1	≤ 0.2	153	156	144
> 0.2	≤ 0.3	159	160	145
> 0.3	≤ 0.4	151	133	156
> 0.4	≤ 0.5	125	134	131
> 0.5	≤ 0.6	139	126	138
> 0.6	≤ 0.7	121	115	128
> 0.7	≤ 0.8	106	117	111
> 0.8	≤ 0.9	99	90	95
> 0.9	≤ 1.0	73	75	73
> 1.0	≤ 1.1	76	77	76
> 1.1	≤ 1.2	62	57	57
> 1.2	≤ 1.3	36	42	44
> 1.3	≤ 1.4	27	34	24
> 1.4	≤ 1.5	8	15	20
> 1.5	≤ 1.6	2	7	12
> 1.6	≤ 1.7	0	0	3
> 1.7	≤ 1.8	0	0	1

Seasonal Effects: The Panel considered whether shifts in the amount of acoustic activity of vaquitas throughout the sampling season (generally from June through early September) could affect estimates of rate of change (see Appendix 3 for raw click data for each station and in each year). The distribution of sampling effort over the sampling season, as well as the pattern of apparent acoustic activity, differed somewhat among years (Figure 4). To avoid any potential biases caused by these differences, the Panel decided to analyze a seasonally reduced dataset that included dates chosen to be those within which at least 50% of the CPODs were operating across all 3 years, i.e., from Julian day 170-231[June 19 to August 19]. This core sampling period included 76.3% of the data, henceforth called the core dataset. The Panel used a Generalized Additive Model (details in Appendix 2) to assess whether the results from truncated dataset differed from using the full dataset (excluding data after September 14, the day prior to the earliest opening of shrimp season over the three years). This sensitivity test showed there were seasonal differences. This affirmed the choice to use the core dataset in order to avoid confounding inter-annual differences in seasonal sampling with potential seasonal differences in vaquita distribution. After discussion about whether it was necessary to model time within year (e.g., month), the Panel agreed that, for the purpose of estimating overall annual rate of change, using a common season across years and pooling data across that core period within a year would deal adequately with seasonal effects. **The Panel agreed that analysis could proceed using the core dataset and by averaging acoustic data within a year for each sampling point.**

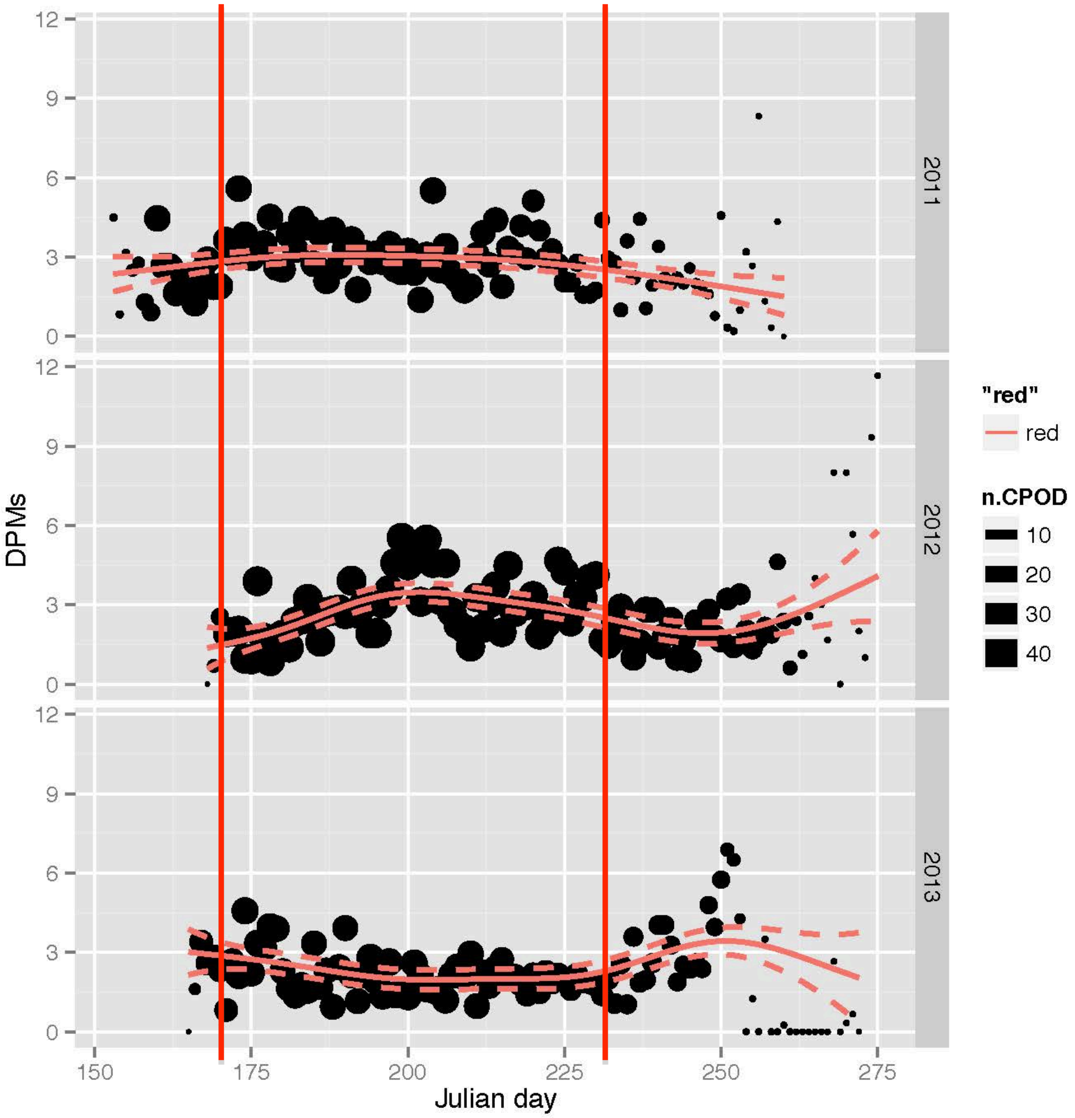

Figure 4. Mean acoustic detection positive minutes (see next section – Acoustic metric – for explanation), averaged across CPODs (y-axis) for each day of sampling (x-axis). Each dot represents a single day of sampling, with dot size proportional to the number of CPODs operating on that day. The red curves represent a smooth (a generalized additive mixed model with separate thin plate regression spline smooth per year, normal errors, identity link, weights that are number of CPODs and auto-regressive error structure of order 1) with approximate 95% confidence interval shown as dashed lines. Vertical red lines indicate the core sampling period from Julian day 170-231.

Acoustic metric: The Panel focused its discussion on two types of measures of vaquita acoustics: clicks/day and detection positive time units (see below for discussion of appropriate time unit). Using acoustic events such as clicks/day to estimate trends in vaquita abundance assumes that acoustic events have a constant relationship with the number of vaquitas. Clicks are the most direct form of the acoustic data, and **Panelists agreed that clicks/day would be the preferred metric as long as the statistical properties were acceptable.** However, Panelists thought it useful to examine the data to see whether the amount of clicking per vaquita might have differed each year (e.g., due to annual differences in prey availability within the sampling area). The number of clicks per Detection Positive Minute (DPM, which is any minute that includes vaquita clicks) was variable, but with a similar pattern between years (Figure 5), which increased confidence in using clicks/day as a reliable acoustic index of vaquita abundance. Additionally, clicks/day was well characterized using a negative binomial distribution in generalized additive models (GAMs) and had no statistical issues in other models used (see details below and in Appendix 2). Nevertheless, the Panel thought analysis using a second metric that would be potentially less sensitive to changes in acoustic behavior would be useful as a sensitivity analysis. In addition to using DPMs, another metric explored was the number of times vaquitas were present ("positive") or not within a time unit that contained most vaquita encounters, where an encounter is determined as a period of detected activity (clicks) defined by silent gaps at each end of more than 30 minutes). The Panel considered different time units, and chose 30 minutes because just over 90% of vaquita encounters were less than 30 minutes in duration (Figure 6). These encounter units are called Detection Positive Half Hours (DPHH). The metric of vaquita positive 30-minute periods was thus used to examine the robustness of the results based on clicks/day.

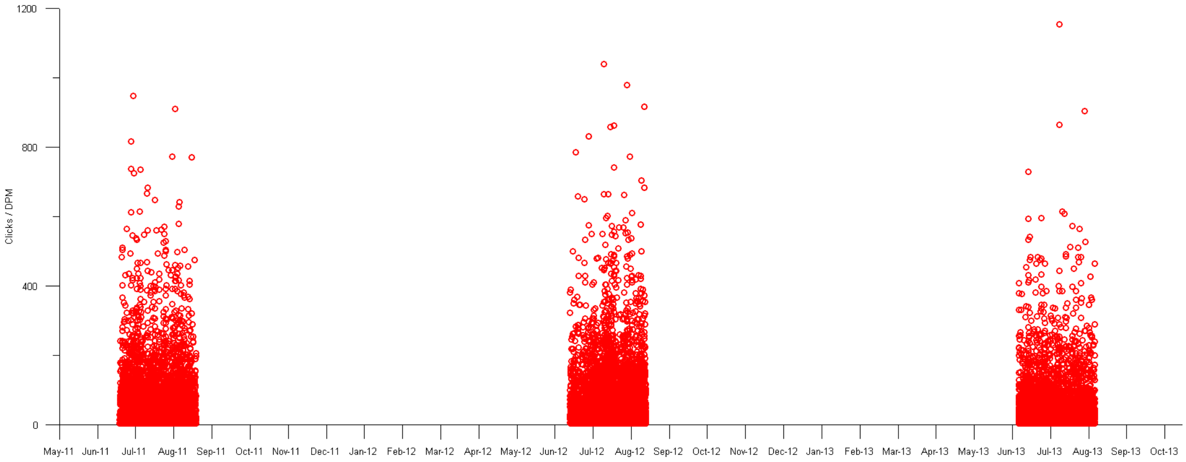

Figure 5. The number of clicks per Detection Positive Minute (DPM) over time.

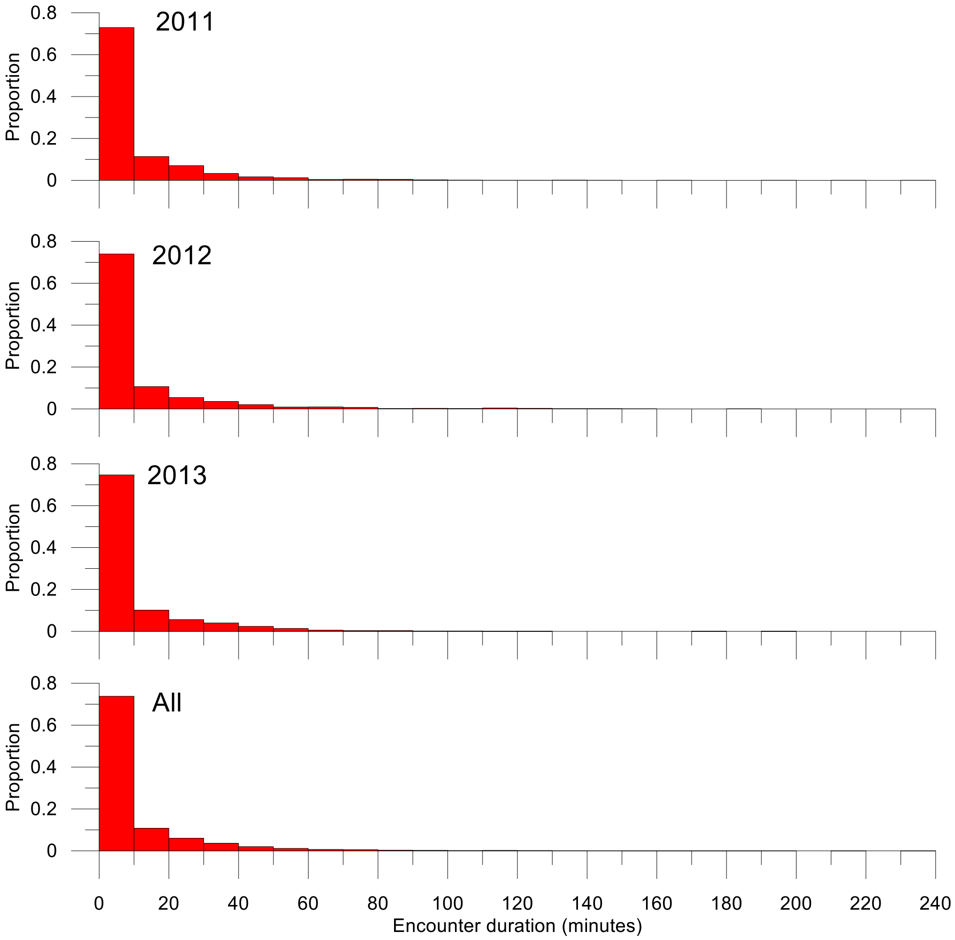

Figure 6. Proportion of vaquita encounters binned by encounter duration.

The relationship between number of DPMs per encounter and encounter duration appears to be linear, although with high variability (Figure 7). Thus, rates of echolocation (as indicated by slope) are nearly constant with increasing encounter duration. Different colors are shown for the three years (red, black and blue respectively from 2011-2013). No differences between years are apparent.

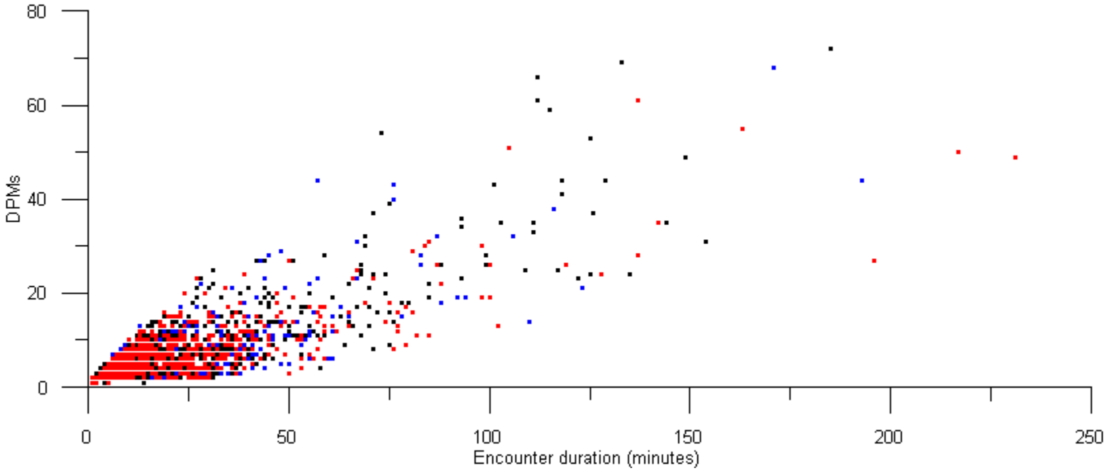

Figure 7. Scatterplot of DPMs for different encounters and for different years.

The GAM models using a negative binomial distribution had a poorer fit using either DPMs or Detection Positive Half Hours (DPHH) per day than using clicks/day (detailed below and in Appendix 2). The DPHH also tended to become saturated (Figure 8). An aggregation of 2 vaquitas could produce similar values of DPM and even more similar values of DPHH as an aggregation of 5 vaquitas, whereas total clicks would be expected to increase more linearly with average group size. This topic is further discussed below under the Spatial GAMs Model.

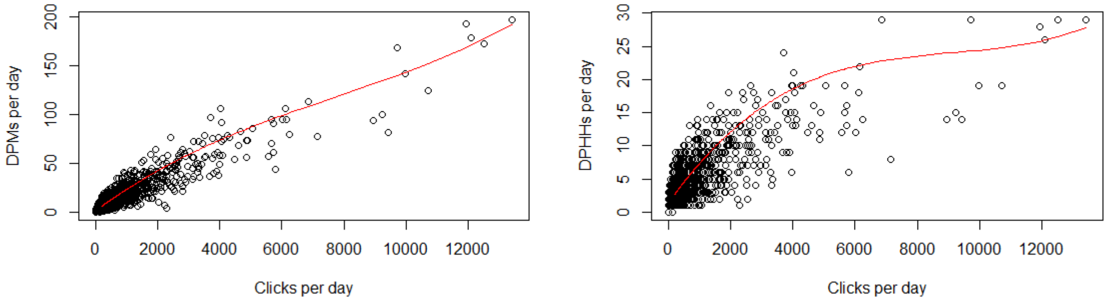

Figure 8. A loess smoothed fits of the number of detection-positive minutes (DPMs) per day (left) and the number of detection-positive half hours (DPHH) per day (right) as functions of the number of vaquita clicks per day for each site and year. Data are limited to the core sampling period.

The Panel agreed that the metric of choice was clicks/day because this metric uses the most raw form of the data and no statistical issues preventing its use.

Agreed scope of inference: The Panel discussed at length the types of analyses that could be performed on the data, and the inferences that could be drawn from the results.

1. **The Panel agreed that the spatial scope of inference should be limited to the CPOD sampling locations.** In other words, predictions from all models would be made only at the sample locations; no attempt would be made to extrapolate the predictions to some wider area such as the entire refuge. Such extrapolations cannot reliably be made from spatial models that omit biologically-relevant explanatory variables; in the present case constructing a detailed spatial habitat model would take far longer than the time available.
2. **Estimates would only be made covering the core sampling period, where at least 50% of the CPODs were operating in all years.** Any analysis would need to account for the fact that some locations did not have CPODs operating for the full time period in each year; data from each location and year should be weighted by the number of sample days.
3. **Inference from the analysis would be based on model-predicted click counts from the model at all sampled locations (n = 45).** An alternative would have been to predict click counts only at locations with no sampling

effort in a particular year, and to use observed click counts at the other locations for making between year comparisons; this approach was rejected firstly because of the uneven number of sampling days across locations (higher sampling error and thus less confidence that the raw data accurately represent activity levels at less frequently sampled locations) and secondly because the observed click counts are extremely variable, likely reflecting variations in vaquita behavior in the vicinity of the CPODs (e.g., variation in animal speed, foraging behavior, etc.) – it was felt that using a model to "smooth out" this variability would result in more reliable inference about trend and provide a better assessment of the uncertainty associated with an estimates.

Description of Models

The Panel agreed to use Bayesian inference approaches for the main models used to estimate rate of change. There are many advantages of using Bayesian methods, but of particular value in the current context was the desire to obtain posterior probability distributions for annual rate-of-change, which in turn allow for straightforward estimation of the probability that the population declined between 2011 and 2013.

After consideration of numerous models, the Panel focused on two models with differing assumptions: the Spatial Model and the Non-Spatial Mixture Model. Here we describe the basis for these models with details in Appendix 2.

Spatial Model Description

The spatial model smoothed over the observed data, considering them to be a noisy version of an underlying smooth pattern of vaquita use. Vaquitas move throughout the study area, and the number of clicks encountered at a station are considered as an imperfect sampler due to stochastic movements of vaquitas. There is also unequal effort at locations, with some locations completely unsampled in some years. The model partitions variability into a spatially smooth surface plus independent random error, where the variance of the independent part decreases proportional to effort (number of sampling days). The estimated surface of vaquita use, then, is the predicted spatial surface. Each year is treated independently for predictions, but autocorrelation parameters are estimated by pooling across years.

The spatial model was a Gaussian log-linear mixed model (i.e., data assumed normal on log scale) with spatially autocorrelated error structure. Rationale for using this approach in favor of others is discussed below (see *Basis for model choice*). Details of this model are in Appendix 2. An overview is provided here.

The response variable data (W_{ti}) were the average number of clicks detected per day at each CPOD location i within a sampling year t. Thus the sample size for analysis was the sum of the number of CPODs functioning during the core sampling period in each year; this totaled 128 “CPOD-years”. The data were transformed by adding 1 and taking the log of the values, i.e,.Y_{ti}= log(W_{ti} + 1), because some functioning detectors recorded zero clicks during some years. The transformed data had reasonable variance:mean properties for using a Gaussian model (Appendix 3).

The transformed data were thus fit by the following model:

$Y_{ti} \sim \text{Normal}(\mu_t + Z_{ti}, \sigma_\varepsilon^2/n_{ti})$,

where μ_t is the expected mean number of clicks per day across locations in year t, $Z_{ti}$is a spatially autocorrelated random effect allowing the number of clicks per day at each location within a year to depart from the overall mean (with CPODs in closer proximity to each other expected to have more similar departures from the overall mean), and σ_ε^2 is the variance for spatially independent random error, weighted by variable sampling effort (number of CPOD-days, n_{ti}) across locations.

Details for estimating the spatial component of the model (Z_{ti}) are in Appendix 2. Worth noting here is that years were treated independently in the model, such that a different spatial surface was estimated from each year’s data, but all years were assumed to have the same autocorrelation structure (same exponential decay in spatial random effect covariance as function of distance between locations). Also note that the spatial model is used to provide predictions forY_{ti} at all K CPOD locations (K = 45), including those not sampled in some years, by drawing on information (through the spatial model parameters) from surrounding CPODs.

Inference was based on several summaries derived from the model parameter posterior distributions. Let S_{ti} be the predicted values for the average number of clicks per day (smoothed over the noisy process with variance σ_ε^2), back-transformed to the original scale of the data,

S_{ti} = exp(μ_t + Z_{ti}) -1

An index of abundance (B_t) is taken to be the average of these values across all KCPOD locations for each year. Thus, given fitted estimates (predicted values) for S_{ti}:

$B_t = \frac{1}{K}\sum_{i=1}^{K} S_{ti}$.

An estimate of the geometric mean annual rate of population change between 2011 and 2013 is calculated as $\lambda = (B_{2013}/B_{2011})^{1/2}$. The proportion of the posterior distribution for this quantity that is less than 1 provides an estimate for the probability that the population in the sampled area has declined between 2011 and 2013.

Posterior summaries including means, medians, variances and credible intervals were obtained from MCMC samples. MCMC specifications (including priors) are detailed in Appendix 2.

Non-spatial Mixture Model Description

The non-spatial mixture model draws on the strength of the sampling design (repeat samples from a fixed semi-regular grid throughout the study area). Predicted click levels at individual CPOD locations were not based on a spatial model. Rather, within a generalized linear mixed model framework, individual CPOD locations were assigned probabilistically to one of $V = 3$ groups based on the level of detections they received across multiple years of sampling. Predictions for individual locations are given by estimated means and random effect variances for the groups to which CPOD locations are attributed.

The parameter of interest is $\theta_{v[k],t}$ the mean click rate (clicks/day) in year t for each of the V groups to which detector k is attributed. Because the data (total clicks per location per year, n_{kt}) were overly dispersed for a Poisson model, they were treated as negatively binomially distributed with the expectation given by the product of the estimated $\theta_{v[k],t}$ and effort (number of CPOD days, d_{kt}), i.e.,

$n_{kt} \sim$ Negative Binomial (p_{kt}, $r_{v[k],t}$),

where p and r are negative binomial parameters, and where $\mu_{kt} = \theta_{v[k],t} d_{kt} = r_{v[k],t}(1-p_{kt})/p_{kt}$ is the expectation for n_{kt}. Thus, variable sampling effort across CPOD locations is handled through its effect on the expectation and variance for n_{kt}.

Exploratory generalized additive model (GAM) analysis suggested that the click-rate data were well described by a negative binomial error distribution (see below).

Individual CPODs were probabilistically assigned to a use-intensity group v based on the data recorded at k across the years during which CPOD k was functioning. In OpenBUGS (Bayesian analysis software), this was done using the "categorical distribution" (multivariate generalization of the Bernoulli):

$v[k] \sim \text{cat}(\mathbf{s}_{vk})$,

where $\mathbf{s}_{vk}$ is the vector of estimated probabilities for k being in group v, which come from a Dirichlet prior distribution (see details in Appendix 2).The degree of certainty in assigning a CPOD location to a particular group depends on how correlated detections were through time; sites with consistently low or high levels of detections are assigned to a group with greater confidence, and all else being equal, CPODs with 3 years of data are assigned more confidently to a group that sites with one or two years of data. Uncertainty in group assignment is propagated through to estimates of other parameters.

In short, the number of detections recorded across all CPODs are assumed to arise from a mixture of V negative binomial distributions. Information across years is shared for the purpose of assigning each CPOD location to a particular group v, but the means and variances for each v, t are independent. Predicted estimates for CPOD locations in years with missing data are based on the probability of belonging to group k, and the conditional mean and variance for group v in year t.

Inference is on the overall mean values for daily click rate (M_t), which are simply the means of the $\theta_{v[k],t}$ weighted by the number of CPODs belonging to each group v, for each t, i.e., $M_t = \frac{1}{K}\sum_{k=1}^{K} \theta_{v[k]t}$. The rate of change between 2011 and 2012 is M_2/M_1. The rate of change between 2013 and 2012 is M_3/M_2. The mean annual rate of change, $\bar{\lambda}$, is the geometric mean of these two values. The probability that the population declined from 2011 to 2013 is the proportion of the Bayesian posterior distribution for $\bar{\lambda}$ that is less than 1. Inference about population change is based on posterior distribution summaries for these derived parameters.

Spatial GAM Models

In addition to the models used to estimate the rate of change, the Panel agreed that a frequentist approach would be useful for efficiently exploring the potential sensitivity of analysis results to some of the Panel's modeling decisions, such as the choice of acoustic metric. However, GAMs were not favored by the Panel as the approach for making inference because GAMs do not provide posterior probability estimates for key parameters of interest.

During the workshop, Generalized Additive Models (GAMs) were developed to quickly evaluate and compare alternative models for estimating population change before implementing those models in Bayesian spatial models. In the GAMs, year was treated as a categorical explanatory variable (2011, 2012 and 2013) and spatial variation was modeled as a two-dimensional thin-plate spline using the *mgcv* package in R. It was assumed that the spatial distribution of vaquitas were the same across years. GAMs that estimated different spatial patterns for each year were generally not stable and are not reported here.

The primary purpose of using GAMs was to test different dependent variables, different error structures, and different mean/variance relationships. Population rates of change were based on mean GAM predictions for the entire set of 45 sampling stations from 2011 to 2013. Additional details on the GAMs are given in Appendix 2.

Basis for model choice

The Panel's charge was to give a best estimate of the current rate of change in vaquita detections. Although the spatial and mixture models gave similar results (see below), the Panel carefully considered the merits of each. Below we summarize the main differences between the two approaches.

- The spatial model assumes that the spatial distribution of clicks is different each year but uses multiple years to estimate the spatial auto-correlation. The non-spatial mixture model assumes that each site falls (probabilistically) into categories of high, medium or low density and that the probability of membership in these categories is shared between years for a given site.

- The spatial model uses information on site location to smooth over random spatial variations in density. The non-spatial model uses no information on site location or proximity between sites.

- The spatial model assumes that the logarithm of mean clicks per day is normally distributed and the non-spatial model assumes that total click counts have a negative binomial distribution.

The Panel agreed that both approaches had merit and that averaging results of the two models would form the best basis for estimating rate of change.

Results and Discussion

Trends in vaquita clicks were first measured using the direct-count method, based only those sites that were sampled in all years (n=39). The direct-counts indicated a total change in the number of recorded clicks of -41% from 2011 to 2013 which is an annual rate of -23.1% per year (negative changes are declines). However, as discussed previously, this method may be biased by non-random survey effort in space and time, and additionally does not provide any estimate of certainty in the true rate of change.

The exploratory GAM analysis showed that total clicks for each site and year could not be adequately modeled with common distribution functions (Poisson, negative binomial and Tweedie distributions). However, the negative binomial distribution provided a very good fit to mean clicks per day for each site and year (Appendix 2), and this distribution was used for subsequent analyses. An analysis with the entire summer dataset was compared to one based only the core sampling period (when at least 50% of CPODS were active in all years). Results showed that click rates trends differed for these two approaches. Of the two, the Panel decided to conduct remaining analyses and base inferences on the core sampling period data, to avoid potential biases caused by unbalanced spatial and temporal coverage in the full dataset (also see Seasonal Effects Section above).

GAM analyses were also used to explore two alternative acoustic measures of vaquita relative abundance: the mean number of minutes per day with vaquita clicks present (detection positive minutes – DPM) and the mean number of half-hour periods per day with vaquita clicks present (detection positive half-hours – DPHH). A negative binomial distribution function was used in a model that fit a common spatial pattern for all years. Results showed that the mean rates of decline for these two metrics (Table 2) were qualitatively similar to declines estimated using the Bayesian spatial model and non-spatial mixture model, but the model fit was not as good as with mean clicks per day (Appendix 2). DPM and DPHH only indicate the presence of vaquitas during a fixed time period and do not indicate the number of animals present. The vaquita distribution is very patchy, and these metrics tend to saturate at higher click count values (Figure 8) and are not thought to provide as much information on relative abundance as the number of clicks. An aggregation of 2 vaquitas might produce similar values of DPM or DPHH as an aggregation of 5 vaquitas. This could explain why the estimated rates of decline for these metrics are less than for the metric based on number of clicks.

Table 2. Estimated annual rates of change estimated from Generalized Additive Models using three different acoustic metrics (see Appendix 2 for details). Confidence limits (CL) are based on analytical estimates of standard error.

Acoustic Metric	Sampling Unit	Annual % Rate of Change	Lower 95% CL	Upper 95% CL
Mean Clicks/day	Yearly mean for each site	-27.2	-43.3	-6.6
Mean DPM/day	Yearly mean for each site	-20.7	-37.3	+0.2
Mean DPHH/day	Yearly mean for each site	-19.1	-36.2	+2.5
Total DPHH	Daily total for each site	-26.1	-30.6	-21.2

In summary, the GAM analyses proved valuable for quickly evaluating the sensitivity of model results to the choice of dataset (affirming choice to use only the core sampling period), acoustic metric (affirming choice to use clicks rather than more aggregated measures), and assumed error distributed (affirming need to model log-transformed data or assume a negative binomial error structure in the case of the non-spatial mixture model). The Panel agreed that mean clicks per day was likely the most sensitive and proportional to changes vaquita abundance. Note that these models assume that the spatial distribution of vaquitas is the same in all three years, and thus differ from the Bayesian spatial model in this respect.

The Panel agreed to use the pooled posterior distributions from both the spatial model and the non-spatial mixture model and to use posterior means as the central estimate. The average trend estimated from the spatial model is a change of -17.5%

per year with a 95% posterior credibility interval from -50% to +26% per year, and the posterior probability of decline is 0.86. The estimated spatial density of vaquitas from the spatial model is illustrated in Figure 9, and the full posterior probability distribution is illustrated in Appendix 2. For the non-spatial mixture model, the average trend is a change of -19% per year. This non-spatial model gave a narrower 95% posterior credibility interval (from -43% to +13% per year, see Appendix 2 for the full posterior probability distribution) and a higher posterior probability of a decline (0.91). Results of these two models are averaged by drawing equally from their respective Bayesian posterior samples for the growth rate parameter. **The model-averaged estimate for population change (Figure 10) has a mean of -18.5% per year and a 95% posterior credibility interval from -46% to +19% per year. The posterior probability of decline is 0.885 and the probability that the decline is greater than 10% per year is 0.753.**

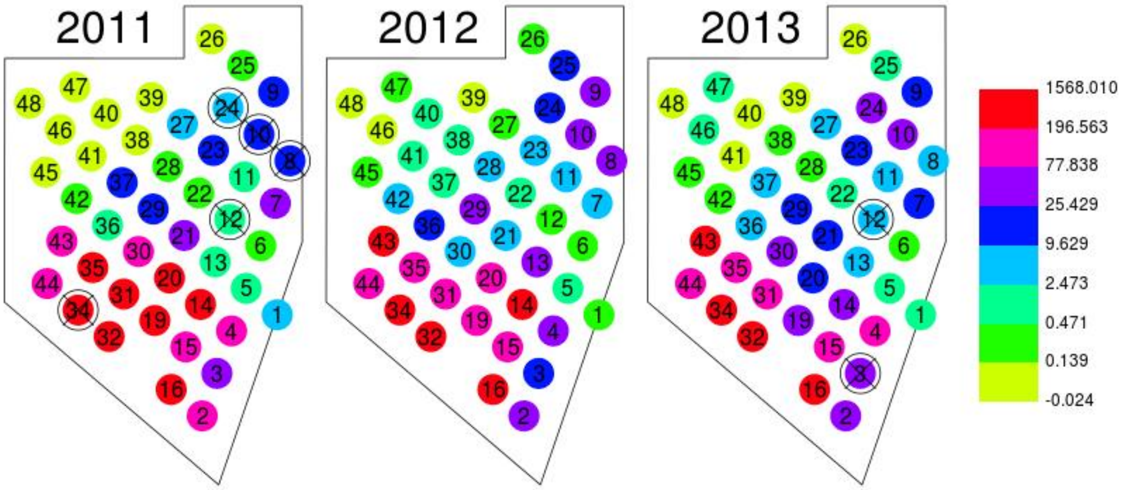

Figure 9. Estimated mean number of clicks per day predicted by the spatial model for the 45 C-POD sites with data for at least one year. Values are posterior medians. Sites with a circle/cross were missing in the indicated year. The analysis did not constrain the density surface to be the same each year.

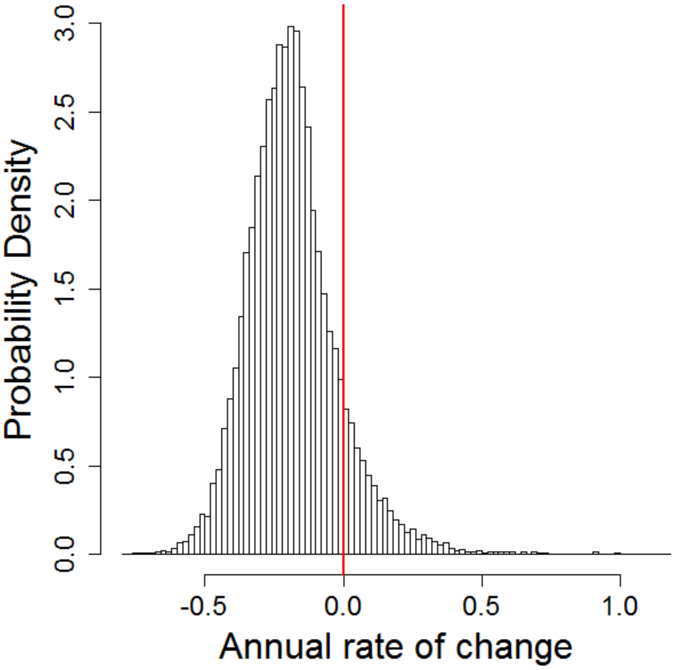

Figure 10. Posterior probability distribution from the pooled spatial and non-spatial mixture models. The mean is a -18.5% change (decline) per year.

The Panel agreed that the estimated rate of -18.5% should be considered as the best estimate of current rate of decline from the acoustic data alone. The Panel agreed that the uncertainty about this rate using only the acoustic data from 2011-2013 does not accurately reflect the actual uncertainty about the current decline of vaquitas because the analyses done in this report do not consider factors like known recent rates of decline and changes in the level of fishing effort. The 2.5% and 97.5% tails of the posterior distribution imply a nearly 50% annual decline for the lower limit and a 19% per year growth for the upper. This upper value is not credible as a population growth rate for vaquitas given the theoretical maximum growth rate for this species (less than 4% growth per year, Hohn et al. 1996) and given recent trends in fishing effort (minutes to the 3rd meeting of the Presidential Commission on Vaquita, September 26, 2013). **The Panel recommends that the analyses conducted here using only the acoustic data from 2011-2013 be used in a population growth model that accounts for these other factors and better characterizes uncertainty in the rates of decline.**

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Appendix 1: **Brief biographies of the Expert Panel**

Dr. Armando Jaramillo-Legorreta was raised in Mexico City and received his bachelor's degree at La Paz, Baja California Sur with a focus on marine biology. His main research interest since 1986 has been in the study of ecology and dynamics of marine mammal populations. He received his Masters and PhD degrees in Baja California with a research focuses on coastal oceanography, population ecology and population dynamics modelling. From 1996 to the present day, he is a researcher for the Marine Mammals Research and Conservation Group of the National Institute of Ecology in charge of the study of habitat use and acoustic monitoring of vaquitas. He was the lead author of the first estimate of abundance of vaquitas in 1997 and the first acoustic monitoring between 1997 and 2008 that informed Mexican Government of the decline of vaquita population. Since 2009 has led the current acoustic monitoring scheme. He has coauthored about 20 papers and chapters on different aspects of marine mammals as well as many technical reports. He is delegate for Mexico at the Scientific Committee of the International Whaling Commission and an advisor on the Mexican National Commission for Biodiversity. He is the current President of the Mexican Society of Marine Mammals.

Dr. Jay Barlow is a research scientist within the Marine Mammal and Turtle Division, SWFSC, La Jolla, where he has worked for 32 years. Jay received his PhD from Scripps Institution of Oceanography (SIO) in 1982. He is the leader of the EEZ Marine Mammals and Acoustics Program within PRD and is an Adjunct Professor at SIO. Dr. Barlow's research involves assessing human impacts on marine mammal populations, estimating their abundance and dynamics, the understanding role of mammals in marine ecosystems, and developing survey methods that use passive acoustics to detect and localize cetaceans. He currently is advisor of three PhD students and serves on dissertation committees of four others. At SIO, Jay teaches a 4-unit course called "Computer-intensive Statistics". Jay serves on many advisory committees both within NOAA (e.g., the NMFS Steering Committee on Assessing Acoustic Impacts on Marine Mammals and the Humpback Whale Biological Review Team) and internationally (e.g., the IUCN Cetacean Specialist Group). Jay has authored or co-authored 110 peer-reviewed journal articles and book chapters, 75 numbered government reports, and edited one book. He has been chief scientist on 12 NOAA and one Australian research surveys.

Dr. Jay VerHoef began his career as a statistician with the Alaska Department of Fish and Game, after receiving a co-major Ph.D. in statistics and ecology and evolutionary biology from Iowa State University. He now works as a statistician for a research lab, the National Marine Mammal Laboratory within the National Marine Fisheries Service of NOAA. For over 25 years, Dr. VerHoef has developed statistical methods and consulted on a wide variety of topics related to plant, animal, and environmental statistics. Dr. VerHoef is a fellow of the American Statistical Association (ASA) and past-Chair of the Section on Statistics and the Environment of ASA. He has over 100 publications, and he is a co-author of a book on spatial statistics. His CV can be found here https://sites.google.com/site/jayverhoef/Home/cv

Dr. Jeff Moore is a research scientist within the Marine Mammal and Sea Turtle Division of the NOAA Southwest Fisheries Science Center in La Jolla, California, where he has worked for five years. Jeff has B.Sc., M.Sc., and Ph.D. degrees in Wildlife Biology from UC Davis, Humboldt State, and Purdue University. Prior to coming to SWFSC, Jeff held post-doc and research faculty appointments at Duke University for four years, where he worked on a global fisheries bycatch assessment for marine 'megafauna' and developing methods for quantifying population impacts of bycatch on long-lived species, and for assessing interactions between developing country small-scale fisheries and coastal marine mammals and sea turtles. Jeff's current research involves assessing human impacts on marine vertebrate populations, estimating abundance and population dynamics parameters using Bayesian statistical methods, and developing quantitative tools to aid management and policy decisions. Jeff serves on advisory committees such as the Biological Review Team for reviewing the status of northeastern Pacific white sharks, and the IUCN Cetacean Specialist Group. He has authored or co-authored > 30 peer-reviewed scientific journal articles since 2004 (3/yr) in addition to numerous NOAA agency technical reports.

Dr. Len Thomas is a senior faculty member within the School of Mathematics and Statistics at the University of St. Andrews, Scotland. He is also director of the world-leading Centre for Research into Ecological and Environmental Modelling (CREEM), an inter-disciplinary research group at the interface between ecology and statistics. Two relevant major focuses of Len's research are statistical methods for population trend estimation (which has been working on since his PhD, at University of British Colombia, Canada, from 1993) and inferences from passive acoustic monitoring of cetaceans (which has been a major topic of research since 2007). One component of the latter has been his involvement in the design and analysis of the SAMBAH survey, a multi-national passive acoustic survey designed to estimate density of harbour porpoise in the Baltic by deploying CPODs at more than 300 sampling locations over a 2 year period, and performing associated calibration experiments. Over the past 21 years, Len has co-authored 67 peer-reviewed papers, 3 books, and a further 57 other publications or technical reports. He has been a keynote speaker at several major international conferences, most recently the International Statistical Ecology Conference (2012, topic: "The future of statistical ecology") and the European Cetacean Society Conference (2013, topic: "Interdisciplinary approaches in the study of marine mammals: ecology meets statistics").

Appendix 2: **Model details**

SPATIAL MODELING OF VAQUITA ACCOUSTIC DATA FROM 2011 – 2013.

Let $W_t(\mathbf{s}_i)$ denote a random variable for mean acoustic click counts at the *i*th spatial location in the *t*th year. Because some of the data were zero, we used $Y_t(\mathbf{s}_i) = \log(W_t(\mathbf{s}_i) + 1)$ for analysis.

To account for uneven effort per site, we divided the spatial model into a spatially structured component and an independent component (often called the nugget effect by geostatisticians). Then the set $\{Y_t(\mathbf{s}_i)\}$ were treated as spatially autocorrelated in a spatial linear mixed model,

$$[Y_t(\mathbf{s}_i) \mid \mu_t, Z_t(\mathbf{s}_i), \sigma_\varepsilon^2, n_{t,i}] = N(\mu_t + Z_t(\mathbf{s}_i), \sigma_\varepsilon^2 / n_{t,i}) \qquad \text{(A.1)}$$

Where $n_{t,i}$ is the number of sampling days for each site for each year. The $n_{t,i}$ account for uneven sampling, and this can be also be viewed as measurement or sampling error in a hierarchical model. Let the vector $\mathbf{z}_t$ denotes all of the spatial random effects, $Z_t(\mathbf{s}_i)$, for the *t*th year,

$$[\mathbf{z}_t \mid \sigma_z^2, \rho] = N(\mathbf{0}, \sigma_z^2 \mathbf{R}_t(\rho)),$$

where we assumed that years were independent, but that the spatial stochastic process had the same autocorrelation model among years; that is,

$$\mathrm{cov}\begin{pmatrix} \mathbf{z}_{2011} \\ \mathbf{z}_{2012} \\ \mathbf{z}_{2013} \end{pmatrix} = \sigma_z^2 \begin{pmatrix} \mathbf{R}_{2011}(\rho) & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{R}_{2012}(\rho) & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{R}_{2013}(\rho) \end{pmatrix}.$$

For spatial autocorrelation, we used the exponential model,

$$\mathrm{corr}(Z_t(\mathbf{s}), Z_u(\mathbf{v})) = \begin{cases} \exp(-3h/\rho) & \text{for} \quad t = u, \\ 0 & \text{for} \quad t \neq u, \end{cases}$$

where h is Euclidean distance. That is, let $\mathbf{s} = (s_x, s_y)$ be the x- and y-coordinates of one point, and $\mathbf{v} = (v_x, v_y)$ be the x- and y-coordinates of another point, then

$$h = \sqrt{(s_x - v_x)^2 + (s_y - v_y)^2}.$$

For the spatial analysis, latitude and longitude coordinates were projected onto the plane using a Universal Transversal Mercator (UTM) projection with a user-defined central meridian. The central meridian was computed as the center of the vaquita refuge. This minimizes distortion from the projection, and UTM is a distance-preserving projection. After projection, the UTM coordinates were converted from meters to kilometers, and translated in space so that 0 on the x-coordinate corresponded with the western-most coordinate of the vaquita refuge, and 0 on the y-coordinate corresponded with the southern-most coordinate of the vaquita refuge.

To complete the model, we specified the following prior distributions,

$$\mu_{2011} \sim \mathrm{UNIF}(-10,10)$$
$$\mu_{2012} \sim \mathrm{UNIF}(-10,10)$$
$$\mu_{2013} \sim \mathrm{UNIF}(-10,10)$$
$$\sigma_z \sim \mathrm{UNIF}(0,10)$$

$$\sigma_\varepsilon \sim \mathrm{UNIF}(0,10)$$
$$\rho \sim \mathrm{UNIF}(0,500)$$

Because the data were modeled on the log-scale, these are flat and non-informative priors that encompassed any reasonable range of values for the parameters. The posterior distribution of the model is,

$$[\sigma_\varepsilon, \sigma_z, \rho, \mathbf{z}, \boldsymbol{\mu} \mid \mathbf{y}]. \tag{A.2}$$

We used Markov chain Monte Carlo (MCMC) methods, using the software package WinBUGS, to obtain a sample from the posterior distribution (A.2). We used a burn-in of 10,000 iterations, and then used 1,000,000 further iterations. For computer storage reasons, we kept a single iteration out of each 100, yielding a sample of 10,000 from the posterior distribution.

We were interested in several summaries derived from the posterior distribution. Let

$$\hat{S}_t^k(\mathbf{s}_i) = \exp[\hat{\mu}_t^k + \hat{Z}_t^k(\mathbf{s}_i)] - 1$$

be a spatially smoothed prediction for the *t*th year, at the *i*th site, and for the *k*th MCMC sample. Notice that these predictions smooth over the noisy process with variance σ_ε^2 contained in the model specification at the data level, and that we are putting the predictions back on the original scale of the data. Then, we take as an indicator of overall abundance, among all *n* sites for each year, as

$$\hat{B}_t^k = \frac{1}{n}\sum_{i=1}^{n} \hat{S}_t^k(\mathbf{s}_i).$$

Finally, we were interested in average rate of change, as a proportion, for the two time increments. We decided to use the geometric mean[2],

$$\hat{r}^k = \left(\frac{\hat{B}_{2012}^k}{\hat{B}_{2011}^k}\frac{\hat{B}_{2013}^k}{\hat{B}_{2012}^k}\right)^{1/2} = \left(\frac{\hat{B}_{2013}^k}{\hat{B}_{2011}^k}\right)^{1/2},$$

and based on this, the posterior probability of a decreasing population can be computed from the mean of

$$\hat{p}^k = I(\hat{r}^k < 1),$$

where *I*(.) is the indicator function. Posterior summaries including means, medians, and variances of $\hat{S}_t^k(\mathbf{s}_i)$, $\hat{B}_t^k$, $\hat{r}^k$, and $\hat{p}^k$, were obtained from the MCMC samples.

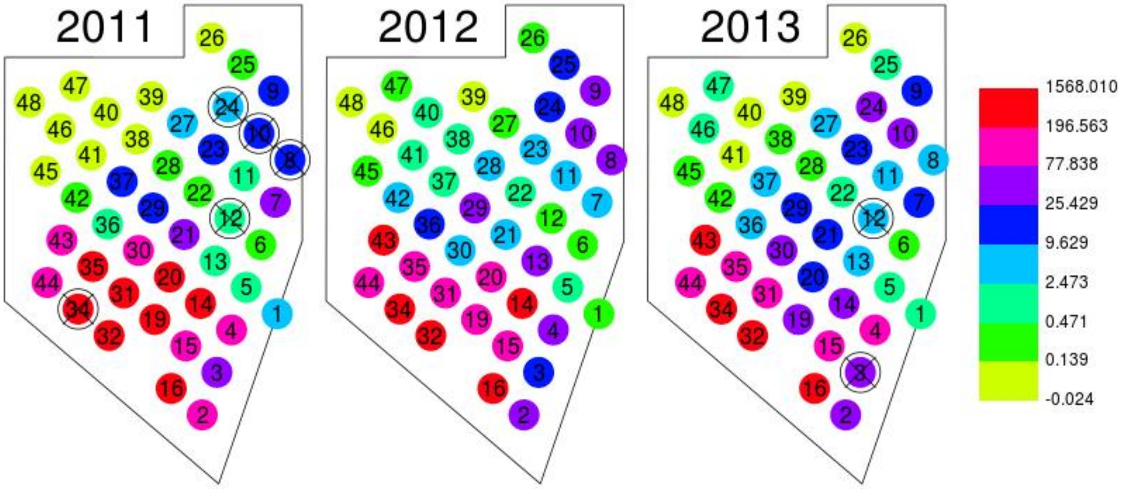
RESULTS

Maps of $\hat{S}_t^k(\mathbf{s}_i)$ for each year and location are given below, where we used the median from the MCMC sample. The sites in 2011 and 2013 with circles around them and an 'x' through the circle indicate that data were missing for those years, so these are spatially interpolated values. Because modeling occurred on the log-scale, these missing values in particular had a wider variance, which had a large effect on the mean value when taking

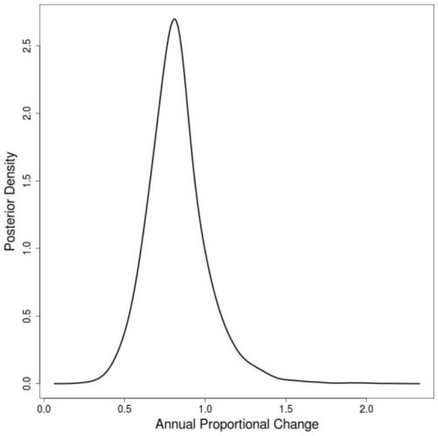
---

[2] Note that $\hat{r}^k$ is the parameter for proportional rate of change which is referred to using the symbol λelsewhere in this Appendix and the body of the report.

exponents to get back on the original scale of the data. So, for presentation purposes, we used the median.



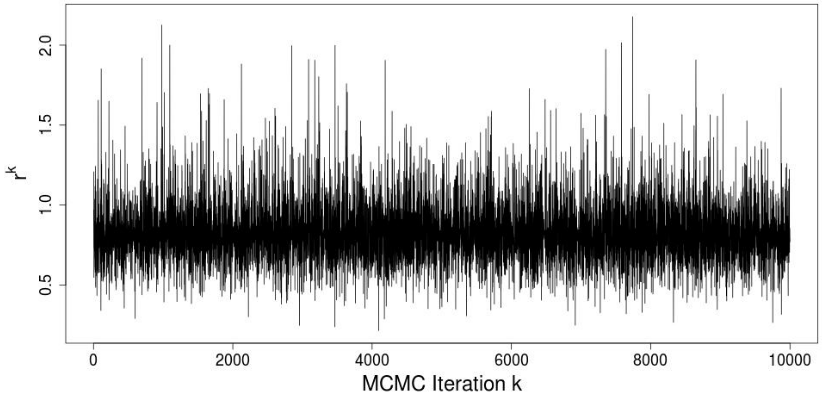
The posterior distribution of the annual proportional change, $\hat{r}^k$, is given below,



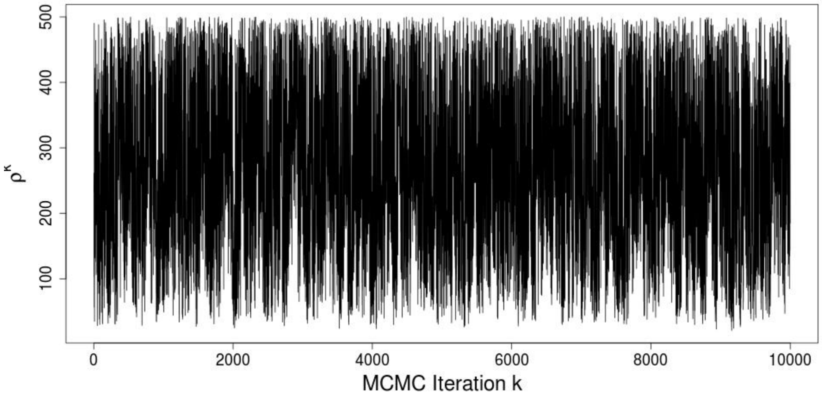
The mean of the posterior distribution for $\hat{r}^k$ was 0.825, and the median was 0.812, indicating about 19% per year decrease in clicks. The 95% credibility interval, based on the 2.5% and 97.5% quantiles, was 0.500 to 1.26. The probability $\hat{r}^k$ was less than one, i.e., $\hat{p}^k$, was 0.862.

ASSESSING THE MODEL AND MCMC

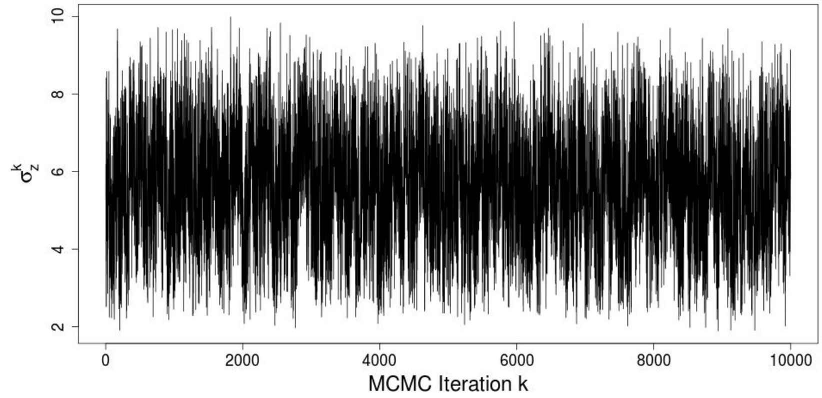
Our primary goal was to obtain a sample of $\hat{r}^k$ in order to project the current population estimate from 2010. To test for convergence in the MCMC chain, we used the Geweke test, found in the R coda package. The result was a *z*-value of 0.863, which is assumed to be a standard normal random variate under the assumption that the MCMC sample is from a stationary distribution. Our result indicates very little reason to be concerned that this particular MCMC chain had not converged. The MCMC trace is shown below.



The trace of ρ is given below,

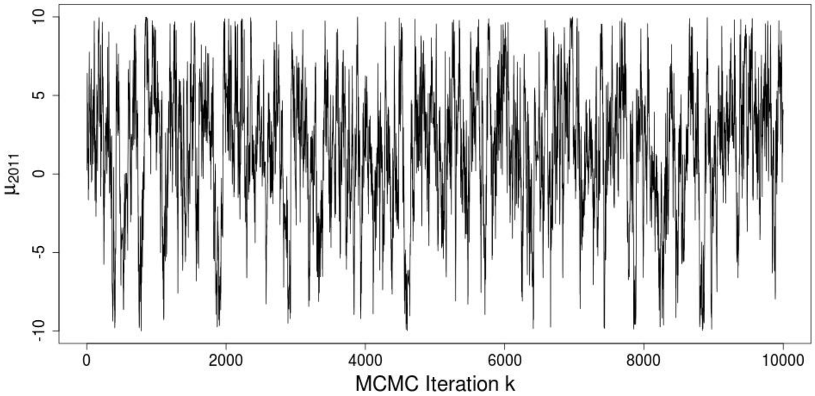


Note that values seem to be truncated by the prior, which has an upper bound of 500. We did a sensitivity analysis, and increased it to 1000. Part of the explanation requires the trace of σ_z as well, which is given below.



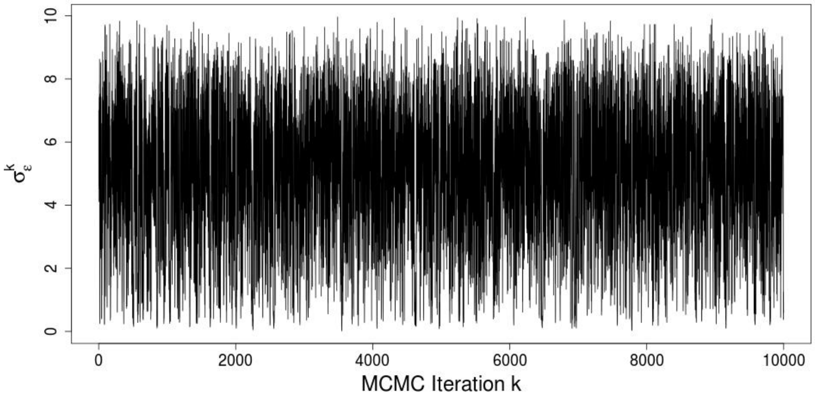
When ρ is increased to 1000, then σ_z becomes truncated by its upper bound of 10. This is a well-known phenomenon in spatial statistics, where the model explores a more linear form of the autocorrelation function by increasing both ρ and σ_z. In fact, the correlation between them, in the MCMC sample, is near 0.86. However, very large values of ρ and σ_z, when they occur together, have little effect on the autocorrelation within the spatial distances seen within the data set. We saw no change in our inferences by continuing to increase either ρ or σ_z, because eventually one of them would become truncated at their upper bound. We left the upper bound for the prior of ρ as 500 (km), as that allowed a lot of autocorrelation among sites, and was far beyond the maximum distance among plots in the vaquita refuge.

The trace of the mean parameters μ_{2011}, μ_{2012}, and μ_{2013} also wander throughout their whole prior distribution. This is shown as a trace of the MCMC sample for μ_{2011} in the following figure,



This may seem strange at first, especially since even the raw data (on the log scale) do not range from -10 to 10. The explanation lies in the fact that spatially autocorrelated random variables, such as the $Z_t(\mathbf{s}_i)$, can wander far from their mean of zero, so the whole set $\{Z_t(\mathbf{s}_i); i = 1,\ldots n\}$ may be positive or negative. To examine this effect, we just chose $Z_{2011}^k(\mathbf{s}_1)$ from the MCMC chain, and its correlation with μ_{2011}^k was -0.988. Thus, the MCMC sampler was behaving as expected.

The trace of σ_ε showed little irregularity, and is given below.



OTHER SPATIAL AND TEMPORAL MODELING CONSIDERATIONS

Table 3 shows the raw data used for spatial modeling. We tried several spatial models, including embedding the spatial linear model into a generalized linear model (called model-based geostatistics by Diggle et al.), where the untransformed data, conditional on the mean, followed a Poisson or negative binomial distribution. However, estimation of site mean values, and even means over sites, was very unstable resulting in average click rates per year, such as $\hat{B}_t^k$, that were often in the thousands.

We also considered a spatial model where the spatial random effects were constant across years, so that the conditional mean in (A.1) was $\mu_t + Z(\mathbf{s}_i)$ rather than $\mu_t + Z_t(\mathbf{s}_i)$. This resulted in much steeper rates of decline, with a mean $\hat{r}^k$ of nearer 0.7 rather than 0.8. The reason can be seen in Table 3, and in particular if we focus on site 34. If the random effects are held constant through the years, then the predicted values in 2011 will largely follow the pattern seen in 2012 and 2013. For 2012 and 2013, site 34 was one of the highest sites, so when that "surface" is shifted to 2011, the predicted values had average values that were nearer 900 to 1000, rather than around 300 seen in Table 3. We felt that it was a strong assumption to hold the spatial surface constant across years, so we rejected the use of that model. Although there are very few data to look at yearly trend (only 2 years for site 34) within site, the current model fits the general trend.

Table 3. Mean click rates per site for each year, along with sampling effort. Median values for $\hat{S}_t^k(\mathbf{s}_i)$ *are shown in bold red for missing C-PODs in those years.*

Site	Mean Clicks 2011	Mean Clicks 2012	Mean Clicks 2013	Sample Days 2011	Sample Days 2012	Sample Days 2013
1	6.05	0.00	2.00	62	60	58
2	157.12	75.13	52.05	41	60	58
3	56.60	9.27	**75.87**	62	60	
4	229.56	26.88	152.48	62	60	58
5	0.00	0.00	0.00	62	60	58
6	0.15	0.00	0.21	62	60	58
7	96.79	4.22	24.35	62	60	37
8	**21.36**	55.20	1.67		60	21
9	24.32	61.67	11.45	62	60	62
10	**13.82**	59.73	38.58		60	62
11	0.71	2.78	2.76	62	60	37
12	**1.91**	0.00	**2.86**		62	
13	0.40	81.65	6.66	58	60	62
14	1781.57	3800.00	83.48	58	60	62
15	158.75	83.57	83.98	57	60	62
16	808.15	287.40	218.06	62	60	62
19	694.00	81.68	23.40	62	59	10
20	365.56	116.37	14.00	62	59	29
21	48.36	1.47	13.78	58	59	37
22	0.00	1.53	0.64	62	59	55
23	37.47	3.73	19.55	62	59	62
24	**7.41**	13.31	37.56		59	62
25	0.00	17.47	1.76	49	62	62
26	0.00	0.00	0.00	52	60	62
27	12.65	0.00	4.66	62	54	62
28	0.00	2.84	0.00	62	62	62
29	10.33	53.81	15.82	57	62	62
30	84.79	3.02	34.58	62	62	62
31	548.44	136.71	115.95	62	62	42
32	527.70	695.37	2116.02	20	62	62
34	**311.95**	408.94	729.91		62	11
35	413.58	77.68	148.84	62	62	50
36	0.67	8.65	4.14	48	62	44
37	26.77	1.82	4.82	47	62	45
38	0.00	0.69	0.29	62	62	62
39	0.00	0.00	0.00	61	55	62
40	0.00	1.37	0.00	62	62	62
41	0.00	0.68	0.00	54	34	62
42	0.00	9.36	0.00	46	61	62
43	252.53	595.46	462.84	62	61	62
44	70.58	172.33	141.65	62	61	62
45	0.00	0.00	0.00	62	61	62
46	0.00	0.00	2.45	48	61	49
47	0.00	0.38	0.56	57	61	62
48	0.00	0.00	0.00	43	61	54

Non-spatial Mixture Model

Rationale: This approach attempts to draw on the strength of the sampling design; Spatial autocorrelation is not modeled.

Basic assumptions:

1. CPOD locations are representative of a sampled area that we wish to make inference about.

2. The mean number of clicks-per-effort-day for a CPOD is linearly related to the amount of use in the area considered to be sampled by that CPOD. Thus clicks-per-effort-day is taken as an index of use-days in the area.

If all CPOD locations had equivalent sampling effort, we could simply take the mean "clicks per effort-day" across CPODs in year t as a robust estimate of the use-index for that year. Inference would be based on comparing the means between years and assessing the probability that they are different (which would depend on the variances of the estimates).

However, data are missing for some CPOD locations in some years (call these missing "CPOD-years"), and precision of the overall mean detection rate could potentially be improved (thereby increasing the power to detect annual changes) by accounting for spatial heterogeneity in CPOD detection rates. Therefore, interpolating the value of the use-index for missing CPOD-years and improving precision in the annual estimates for the use-index are the analysis objectives.

Data

n_{kt} = number of clicks recorded at location k, year t

d_{kt} = number of effort-days at location k, year t

K = 45 = total number of CPOD locations with effort in at least one year

The data are truncated in time, i.e., only using recorded clicks and effort-days between Julian dates 170 and 231 (inclusive).

Model

The non-spatial mixture model draws on the strength of the sampling design (repeat samples from a fixed semi-regular grid throughout the study area), emphasizing a design-based rather than model-based approach to inference. Predicted click levels (mean number of clicks per season, n_{kt}) at individual CPOD locations are not based on a spatial model. Rather, within a generalized linear mixed model framework, individual CPOD locations are assigned probabilistically to one of V = 3 groups based on the level of detections they received across multiple years of sampling.

Predictions for individual locations are given by estimated means for the groups to which CPOD locations are attributed, i.e.,

$$n_{kt} \sim \text{Negative Binomial}\ (p_{kt}, r_{v[k],t}),$$

wherep and r are negative binomial parameters. Exploratory generalized linear model (GAM) analysis suggested that the click-rate data were well described by a negative binomial error distribution (see GAM section below). The expectation for n_{kt} (which we denote μ_{kt}) is a function of the expected mean number of clicks per day ($\theta_{v[k],t}$) and sampling effort (d_{kt}). The former depends on the group membership for CPOD k and the year:

$$\mu_{kt} = \theta_{v[k],t} d_{kt}.$$

For the negative binomial, the expectation $\mu_{kt} = r_{v[k],t}(1-p_{kt})/p_{kt}$. We placed priors on $\theta_{v[k],t}$ and $r_{v[k],t}$(see below), so that in each MCMC iteration, the value for $p_{kt} = r_{v[k],t}/(r_{v[k],t} + \mu_{kt})$.

CPOD location k is probabilistically assigned to a use-intensity group v based on the data recorded at k across the years during which CPOD k was functioning. In OpenBUGS, this was done using the “categorical distribution” (multivariate generalization of the Bernoulli):

$$v[k] \sim \mathrm{cat}(\mathbf{s}_{vk}),$$

where $\mathbf{s}_{vk}$ is the vector of probabilities for k being in group v, which come from a Dirichlet prior distribution:

$$\mathbf{s}_{vk} \sim \mathrm{Dirichlet}(\boldsymbol{\alpha}_v),$$

where $\boldsymbol{\alpha}_v$ are the Dirichlet intensity parameters. Setting $\alpha_1 = \alpha_2 = \alpha_3 = 1$ makes this distribution fairly uninformative, providing the flexibility for s_{vk} to take on any values that sum to 1 (across v for each k).

The degree of certainty in assigning a CPOD location to a particular group depends on how correlated detections are through time; sites with consistently low or high levels of detections (or with more years of information, since there were some missing CPOD-years) are assigned to a group with greater confidence. Uncertainty in group assignment is propagated through to estimates of other parameters.
In short, the number of detections recorded across all CPODs are assumed to arise from a mixture of V negative binomial distributions in each year. Information across years is shared for the purpose of assigning each CPOD location to a particular group v, but the means and variances for each v, t are independent. Predicted estimates for CPOD locations in years with missing data are based on the probability of belonging to group v, and the conditional expected mean and variance for group v in year t.

Inference is on the overall mean values for daily click rate (M_t), which are simply the means of the $\theta_{v[k],t}$ weighted by the number of CPODs belonging to each group v,for each t, i.e., $M_t = \frac{1}{K}\sum_{k=1}^{K} \theta_{v[k]t}$. The rate of change between 2011 and 2012 is M_2/M_1. The rate of change between 2013 and 2012 is M_3/M_2. The mean annual rate of change, $\bar{\lambda}$, is the geometric mean of these two values. The probability that the population declined from 2011 to 2013 is the proportion of the Bayesian posterior distribution for $\bar{\lambda}$ that is less than 1. Inference about population change is based on posterior distribution summaries for these derived parameters.

Additional assumptions

In addition to the basic assumptions above, we note the following:

1. We used V = 3 groups based on visual inspection of the data, which indicates locations for which the mean number of clicks per effort day is consistently extremely low (just a few clicks/day), very high (clicks/day = hundreds to low thousands), or in-between (clicks per day = tens). Using fewer groups, such as V = 1 (single group, no mixture), ignores this information, potentially biasing estimates of $\mu_{k,t}$ for missing CPOD-years (and hence for the M_t. On the other hand, assuming many groups (V > 3) may result in over-fitting the data, reducing precision in the estimates of $\mu_{k,t}$ and thus increasing uncertainty in M_t. In practice, data generated by a mixture of many processes tend to be well approximated by mixture models with just a few groups.

2. Justification for this general approach relies on the assumption that there are fixed high-use and low-use areas through time, i.e., *on average*, locations with the highest click-rates in two years will also have the highest click rates in the third year. However, the assumption, as modeled, allows for some flexibility in how the implied spatial patterns of vaquitas vary through time, because the mean click-rate differences between groupings are estimated independently for each year. Thus, for example, the mean click rate for "medium use" CPODs could theoretically be much higher than "low use" CPODS in one year but only slightly higher in another year. Simple Spearman correlations suggest that it is indeed reasonable to assume that relative use across individual CPODs was similar through time ($\mathrm{rs}_{2011,2012} = 0.77$; $\mathrm{rs}_{2012,2013} = 0.93$; $\mathrm{rs}_{2011,2013} = 0.83$). Similarly, high certainty in the assignment of most CPODs to a particular one of the *V* groups (see below) provided additional support for this assumption.

3. In contrast with spatial models, we are not borrowing information from surrounding CPODs to estimate values for CPOD *k*. All CPOD locations are treated as independent sample locations. The expected value for CPOD *k,t* depends on which group *k* belongs to (which is informed by data in other years at *k*) and on the mean and variance parameters for the group (which are informed by other CPODs in the same group, but irrespective of their proximity to *k*).

MCMC specifications

An MCMC chain of length 1,000,000 was run. The first 500,000 samples were discarded. Every 100th sample from the chain was retained, so that the posterior distributions were to constructed from 10,000 samples.

The following prior distributions were used:

$\mathbf{s}_{vk}$ ~ Dirichlet(1, 1, 1) # Probability of CPOD k belonging to group v

$\log(\theta_{v[k],t})$ ~ Normal(−10, σ^2=1000), for v = 1;

$\theta_{v[k],t} = \theta_{v-1[k],t} + \exp[\Delta\log(\theta_{v[k],t})]$, for $v = 2, 3$

$\Delta\log(\theta_{v[k],t})$ ~ Normal(5, σ^2=1000) (left-truncated at zero to be positive)

$r_{v[k],t}$ ~ Categorical(**z**)[3], where **z** is a vector of probabilities for r = integers from 1 to 10;

z_r ~ Dirichlet(1) for all r

$p_{kt} = r_{v[k],t}/(r_{v[k],t} + \mu_{kt})$ # Negative binomial parameter

Results

Most CPODs were attributed to mixture group with high probability, though assignment was less clear (but still fairly confident) in a few cases (see examples in Figure 11).

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[3] In WinBUGS and OpenBUGS, the negative binomial r parameter must be an integer ≥ 1.

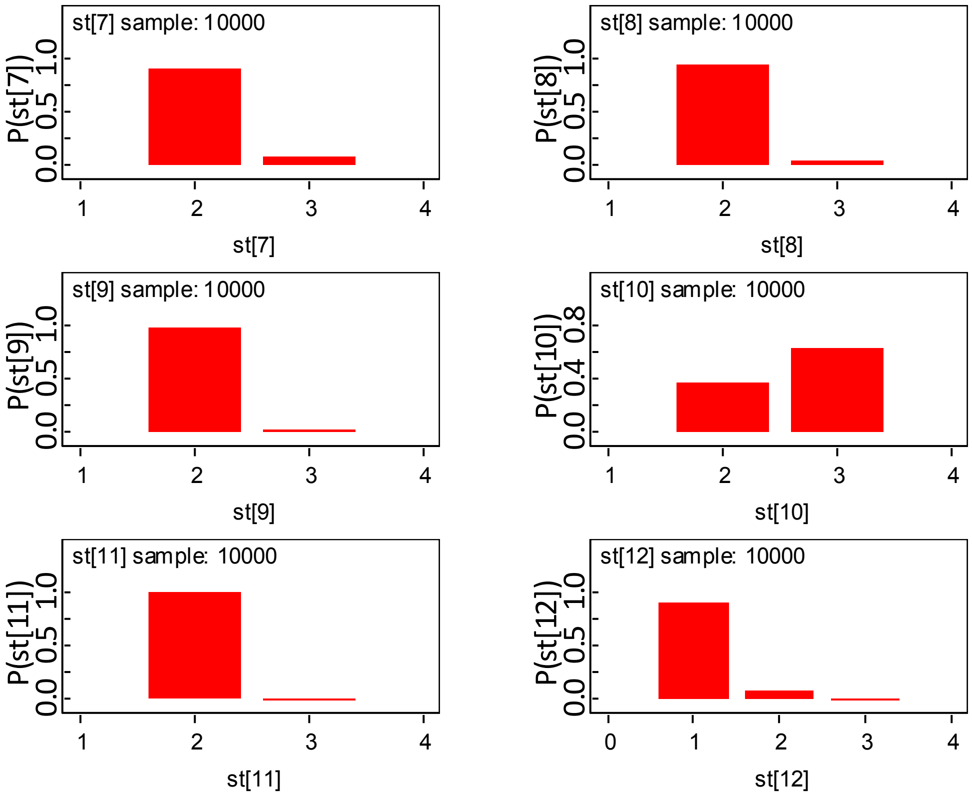


Figure 11. Sample OpenBugs output. Posterior densities for assignment of individual CPODs to one of three mixture groups. CPODs 7 – 12 shown here for example. CPODs 7, 8, 9, 11 were assigned to group 2 with *high certainty. Detector 12 was assigned to group 1 with fairly high certainty. CPOD10 was assigned with the least certainty of all CPODs.*

Figure 12 shows annual predictions of mean click rate (average number of clicks per day) for the 45 CPODs that functioned in at least one year. Values depend on the mixture group to which the CPOD is most commonly assigned. Assignment of CPODs to mixture groups was generally clear. Detectors receiving almost no clicks in any year were assigned to one group; detectors receiving on the order of tens of clicks per day were assigned to a different group; and detectors receiving an average of hundreds of clicks per day in at least one year tended to be assigned to the third group. This third group was the most variable; hence the expected clicks/day for CPODs in this group had the highest variance, as indicated by broader credible interval bars, but overall the pattern of residuals indicated reasonable fit of this model to the data.

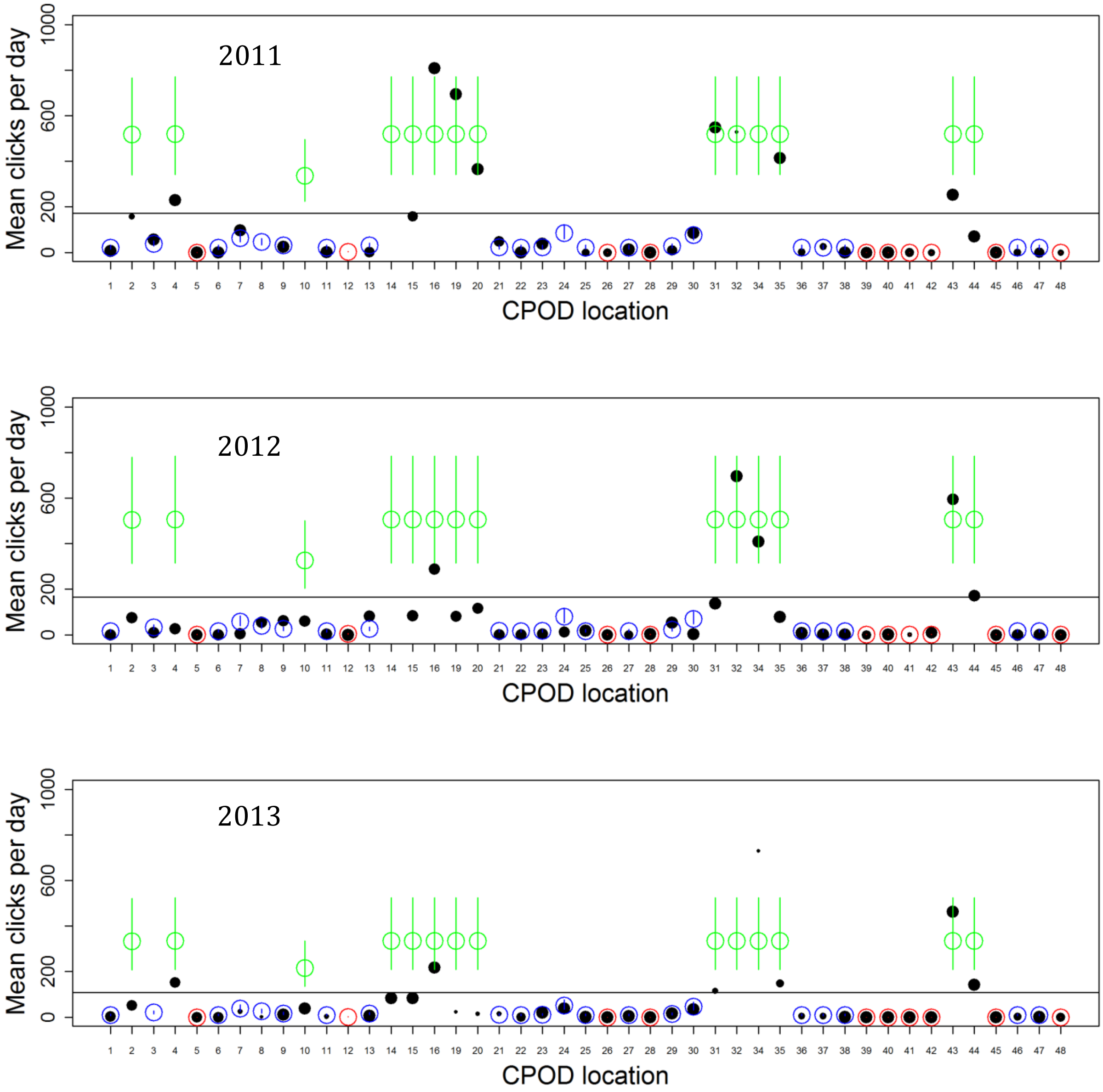


Figure 12. A) Observed and expected values for "mean clicks per day" at each CPOD location that functioned in at least one year, 2011 to 2013. Solid black points are the observed values, with point size indicating the relative level of effort (large circles = more days of sampling). Open circles are the model-expected values (with 90% credible intervals),$\theta_{v[k],t}$ *,for the three mixture groups (with most likely group indicated by different colors). Horizontal black line is the estimated overall mean for the year,* M_t*. Here, the y-axis only goes to 1000 (so that lower estimates may be visually resolved).*

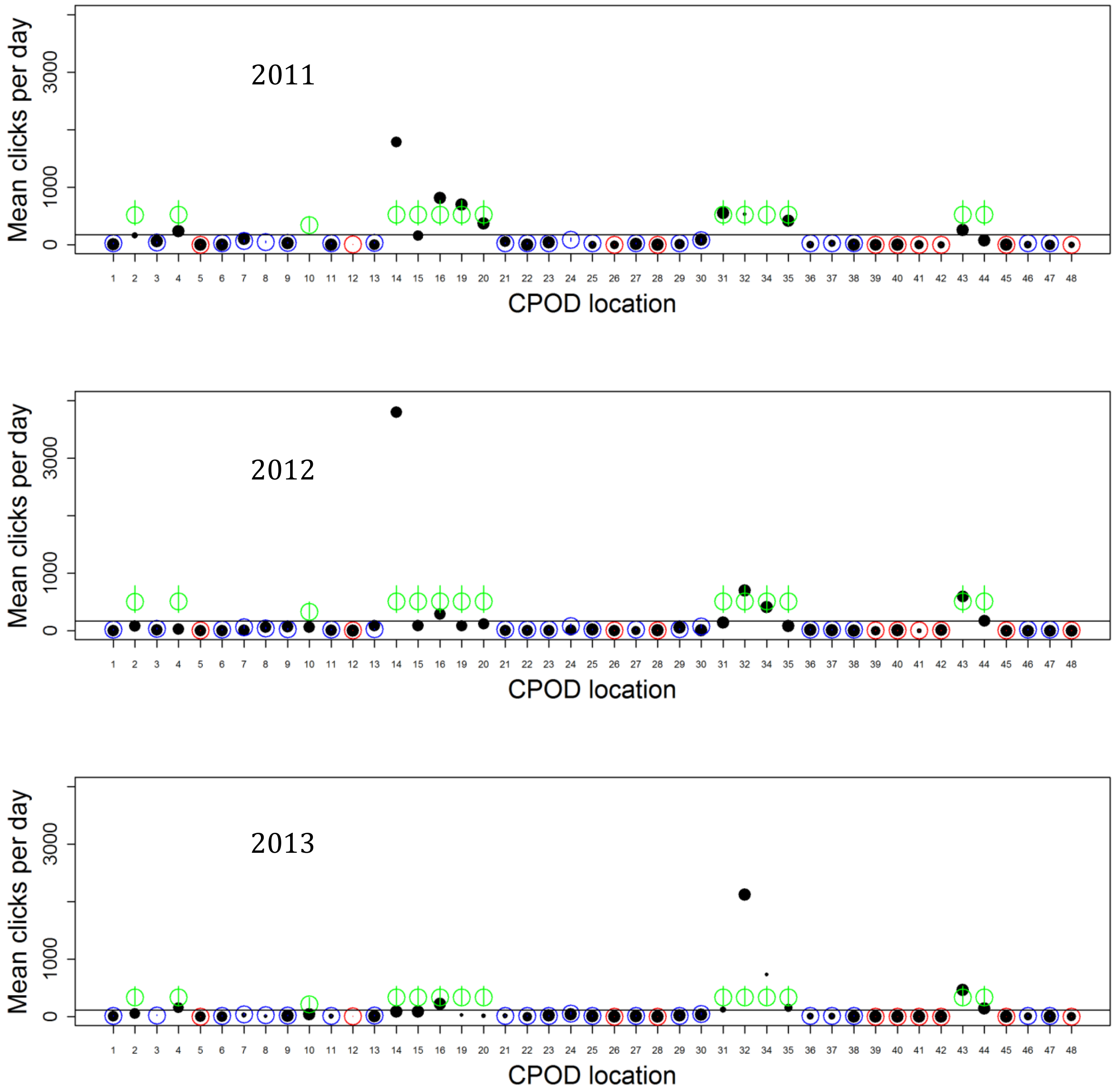


Figure 13. B) Same as in A but the y-axis goes to 4000 to show data extremes.

The posterior mean for $\bar{\lambda}$ was 0.81 with a 95% credible interval ranging from 0.57 to 1.13 (Figure 14). The probability that $\bar{\lambda}$ is less than 1 was 0.91.

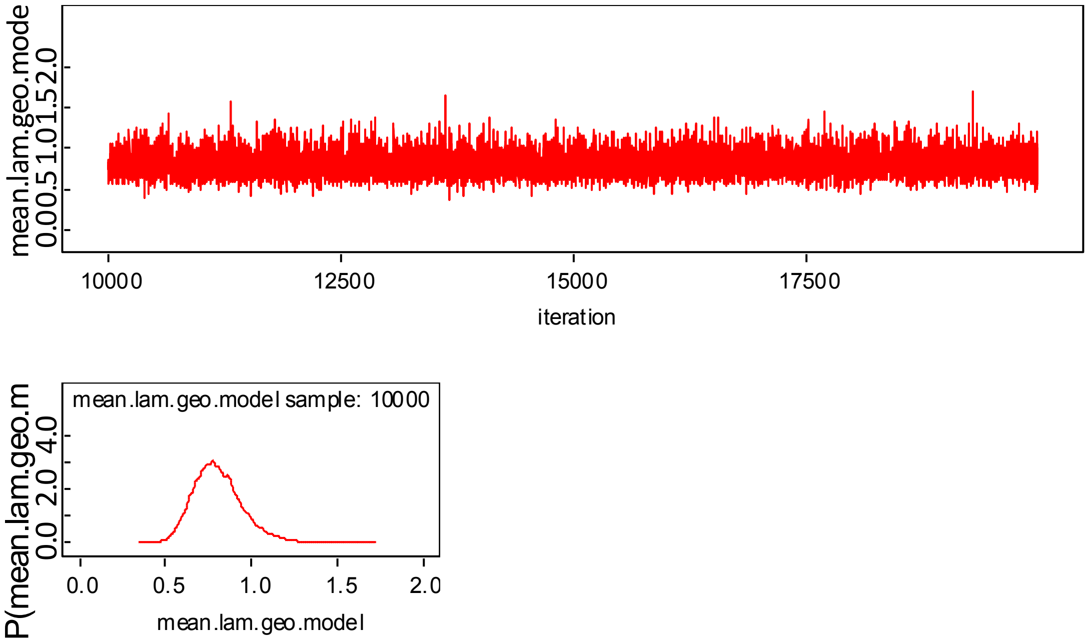


Figure 14. OpenBugs output for $\bar{\lambda}$ *, the geometric mean of* M_3*/* M_2 *and* M_2*/* M_1*Top panel shows the retained MCMC samples.*

Generalized Additive Models

Vaquita Trend Analyses with Generalized Additive Models (GAMs)

Introduction

Generalized Additive Models (GAMs) were developed to quickly evaluate and compare alternative models for estimating population change before implementing those models in Bayesian models. In the GAMs, year was treated as a categorical explanatory variable (2011, 2012 and 2013) and spatial variation was modeled as a two-dimensional thin-plate spline using the *mgcv* package in R (v. 3.0.1). It was assumed that the spatial distribution of vaquitas was the same across years and that, between years, relative densities changed proportionately among all sites. GAMs that estimated different spatial patterns for each year were generally not stable and are not reported here. The spatial distribution was modeled using all years, but inference on the rate of change in population size was based on the ratio of mean of predicted values in 2013 to the mean predicted values in 2011. To maintain a balanced geographic coverage for this comparison, spatial predictions were made using *predict.gam* on the grid of 45 C-POD stations for which data were available in at least one year. Unless noted otherwise, the GAM analyses were based on the core sampling period (between Julian days 170 and 231, inclusive) when at least 50% of C-POD stations were deployed in each year.

Three common statistical distributions (Poisson, negative binomial and Tweedie distributions) were fit to each dependent variable used, and the best fit was evaluated by visual appraisal of the QQ plots. The negative binomial provided the best fit to all the dependent variables explored here. Within *mgcv*, the binomial parameter *theta* was specified as a range and that range was adjusted as necessary to ensure that best-fit value was not outside the range of potential values. When a mean of daily values was used as a dependent variable, the number of days was used as an offset to account for the unequal sample size.

Model Results

When total clicks per day were used as a dependent variable, none of the statistical models provided a good fit, but the negative binomial (Fig. 15) fit better than the Poisson or Tweedie distributions. This model (below) estimated a decline of 24.0% per year from 2011 to 2013. Due to the lack of fit between the data and the assumed distribution, inferences based on this model should not be trusted. Total clicks per day were not considered in any subsequent models.

```
Family: Negative Binomial(0.058)
Link function: log

Formula:
Clicks ~ as.factor(Year) + s(x, y, bs = "tp")

Parametric coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)           2.3490     0.1017  23.104< 2e-16 ***
as.factor(Year)2012  -0.1428     0.1266  -1.128    0.259
as.factor(Year)2013  -0.5482     0.1326  -4.135 3.55e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
edfRef.dfChi.sq p-value
s(x,y) 28.66  28.99   2567  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.193   Deviance explained = 39.5%
UBRE score = -0.51513  Scale est. = 1         n = 7269
```

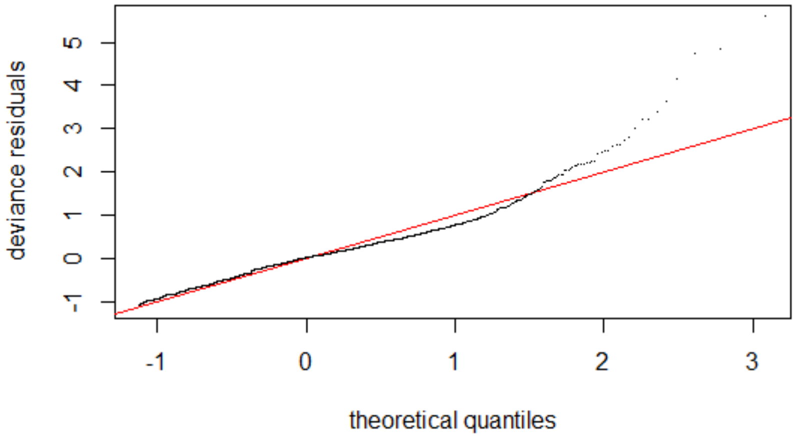


Figure 15. Quantile-quantile plot showing how well the best statistical distribution (negative binomial) fit the distribution of total clicks per day. Ideally, all the points would fall on the line if the theoretical distribution fit the distribution of the data perfectly.

When mean clicks per day (averaged over all days for a given site and year) was used as a dependent variable, a negative binomial distribution provided a very good fit to the data. This model (below) explained 81% of the deviance in the data and estimated a decline of 27.2% per year from 2011 to 2013.

```
Family: Negative Binomial(1.011)
Link function: log

Formula:
Clicks ~ as.factor(Year) + s(Lat, Long, bs = "tp") + offset(log(Days))

Parametric coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          -1.2218     0.2017  -6.057 1.38e-09 ***
as.factor(Year)2012  -0.5075     0.2501  -2.029   0.0424 *
as.factor(Year)2013  -0.6358     0.2546  -2.497   0.0125 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
edfRef.dfChi.sq p-value
s(Lat,Long) 26.24  28.38  488.6  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.0484   Deviance explained = 81.1%
UBRE score = 0.74932  Scale est. = 1         n = 128
```

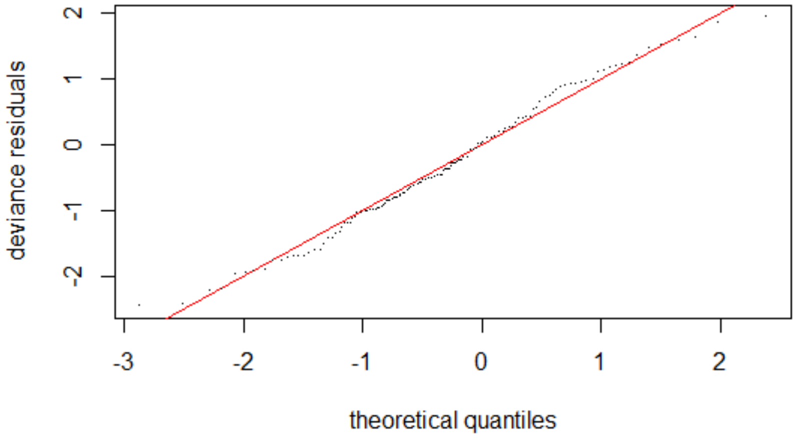


Figure 16. Quantile-quantile plot showing how well the best statistical distribution (negative binomial) fit the distribution of mean clicks per day (averaged over all days for each station and year). Note that the negative binomial distribution provided a much better fit for mean clicks per day than for total clicks per day (Figure 15).

The previous analysis was limited to the core sampling period. The same analysis was repeated using the entire sampling period from the initial deployment of C-PODs each year just before the earliest start of the shrimp fishing season in all three years (i.e, until September 14, Julian day 254). The resulting model (below) gave a lower estimate of the rate of decline (17.4% per year). By prior agreement of the expert panel, this longer sampling period was not used in subsequent analyses because the unequal spatial and temporal distribution of C-POD deployments would not provide robust estimates of the rate of decline.

```
Family: Negative Binomial(0.893)
Link function: log

Formula:
Clicks ~ as.factor(Year) + s(x, y, bs = "tp") + offset(log(Days))

Parametric coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          -1.2318     0.1935  -6.365 1.96e-10 ***
as.factor(Year)2012  -0.4050     0.2572  -1.575    0.115
as.factor(Year)2013  -0.3825     0.2615  -1.463    0.144
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
edfRef.dfChi.sq p-value
s(x,y) 26.85   28.7  448.7  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.204   Deviance explained = 77.5%
UBRE score = 0.76634  Scale est. = 1         n = 128
```

Some previous studies of relative porpoise abundance using C-PODs have been based on detection positive minutes, that is the number of minutes per day with at least one porpoise click. When mean detection positive minutes (DPM) per day (averaged over all days for a given site and year) was used as a dependent variable, a negative binomial distribution provided a reasonable fit to the data (Figure 17). This model (below) explained 86% of the deviance in the data and estimated a decline of 20.7% per year from 2011 to 2013, which is less than the rate of decline estimated using mean clicks per day (see Table 2 in Report body).

```
Family: Negative Binomial(3.93)
Link function: log

Formula:
DPMs ~ as.factor(Year) + s(x, y, bs = "tp") + offset(log(Days))

Parametric coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          -4.5919     0.3275 -14.020   <2e-16 ***
as.factor(Year)2012  -0.5241     0.2320  -2.259   0.0239 *
as.factor(Year)2013  -0.4651     0.2395  -1.942   0.0522 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
edfRef.dfChi.sq p-value
s(x,y) 18.95  22.86  240.9  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =   0.51   Deviance explained = 86.4%
```

```
UBRE score = 0.14129  Scale est. = 1         n = 128
>Predictions= exp(predict.gam(NBmeanDPMs,newdata=PredictSurface))
>ratio2013to2011=
mean(Predictions[PredictSurface$Year==2013])/mean(Predictions[PredictSu
rface$Year==2011])
>ratio2013to2011; 1-sqrt(ratio2013to2011)
[1] 0.6281017
[1] 0.2074713
```

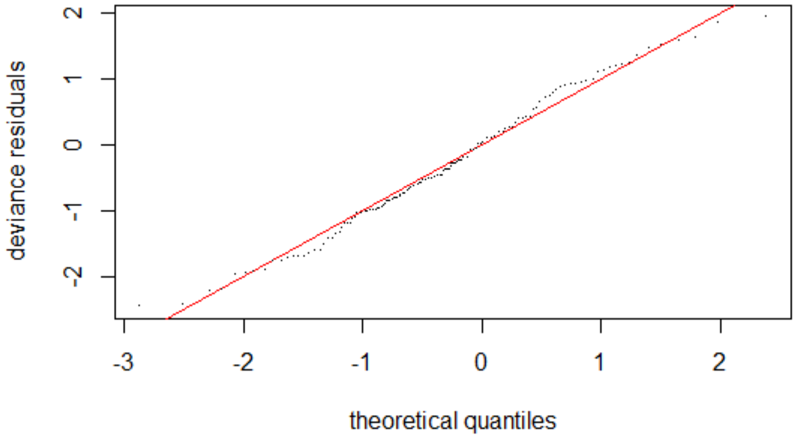


Figure 17. Quantile-quantile plot showing how well the best statistical distribution (negative binomial) fit the distribution of detection positive minutes (averaged over all days for each station and year).

We also explored the potential of using detection positive half-hour periods as a measure of relative vaquita density, that is the number of half-hour periods per day with at least one porpoise click. Preliminary analyses during the workshop showed that the vast majority of porpoise detections lasted less than half an hour, so half-hour periods should be relatively independent of each other. When mean detection positive half-hours (DPHH) per day (averaged over all days for a given site and year) was used as a dependent variable, a negative binomial distribution provided a marginally good fit to the data (Figure 18). This model (below) explained 78% of the deviance in the data and estimated a decline of 19.1% per year from 2011 to 2013, which is less than the rate of decline estimated using mean clicks per day (see Table 2 in Report).

```
Family: Negative Binomial(99186)
Link function: log

Formula:
DPHHs ~ as.factor(Year) + s(x, y, bs = "tp") + offset(log(Days))

Parametric coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          -5.2635     0.3407 -15.449   <2e-16 ***
as.factor(Year)2012  -0.4830     0.2322  -2.080   0.0375 *
as.factor(Year)2013  -0.4244     0.2420  -1.754   0.0795 .
---
```

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
edfRef.dfChi.sq p-value
s(x,y) 15.45  19.39  154.2  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.695   Deviance explained = 78.4%
UBRE score = -0.035104  Scale est. = 1         n = 128
```

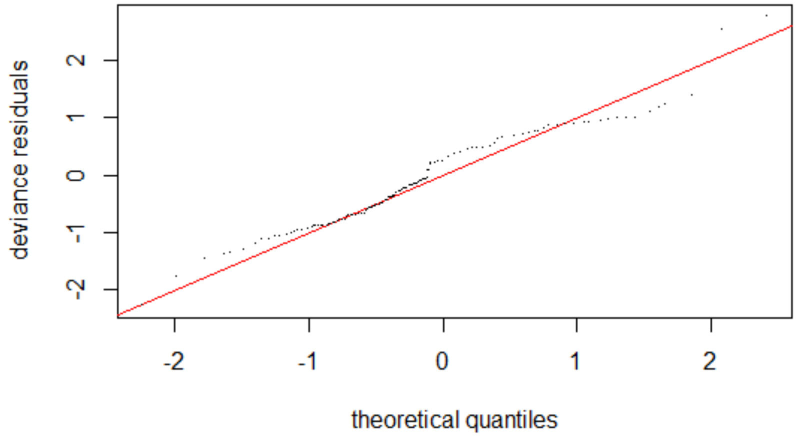


Figure 18. Quantile-quantile plot showing how well the best statistical distribution (negative binomial) fit the distribution of detection positive half-hours (averaged over all days for each station and year). Note that the negative binomial distribution did not fit detection positive half-hours as well as it fit detection positive minutes (Fig. 14).

A better fit was obtained using total DPHH per day instead of using the mean DPHH. The negative binomial distribution fit total DPHH (Figure 19) much better than total clicks (Figure 15). That total DPHH model result is given below. The resulting rate of population decline for this model (26.1% per year) is very similar to that for the mean clicks per day model (27.2%, see first model above).

```
Family: Negative Binomial(0.833)
Link function: log

Formula:
DPHHs ~ as.factor(Year) + s(x, y, bs = "tp")

Parametric coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)         -1.79679    0.09183 -19.567  < 2e-16 ***
as.factor(Year)2012 -0.43563    0.06011  -7.247 4.26e-13 ***
as.factor(Year)2013 -0.60411    0.06472  -9.335  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
edfRef.dfChi.sq p-value
s(x,y) 27.85  28.84   2983  <2e-16 ***
```

```
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.422   Deviance explained =   64%
UBRE score = -0.45903  Scale est. = 1         n = 7269
```

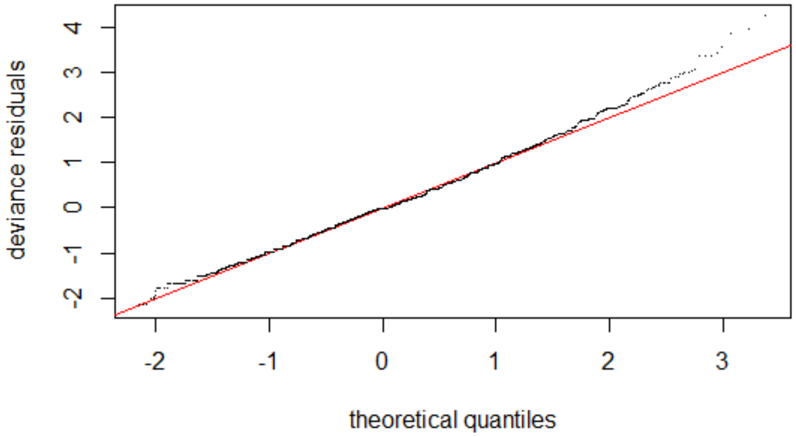


Figure 19. Quantile-quantile plot showing how well the best statistical distribution (negative binomial) fit the daily total of detection positive half-hours.

Appendix 3: **Further data description**

There were two efforts that were useful to Panelists in interpreting the data and considering how to choose an appropriate model. Station numbers are given in Figure 20. The first helpful effort was a representation of clicks through time for each station and for each year (Figure 21). The second analysis showed the relation between the mean and variance for mean clicks/CPOD day (Figure 22).

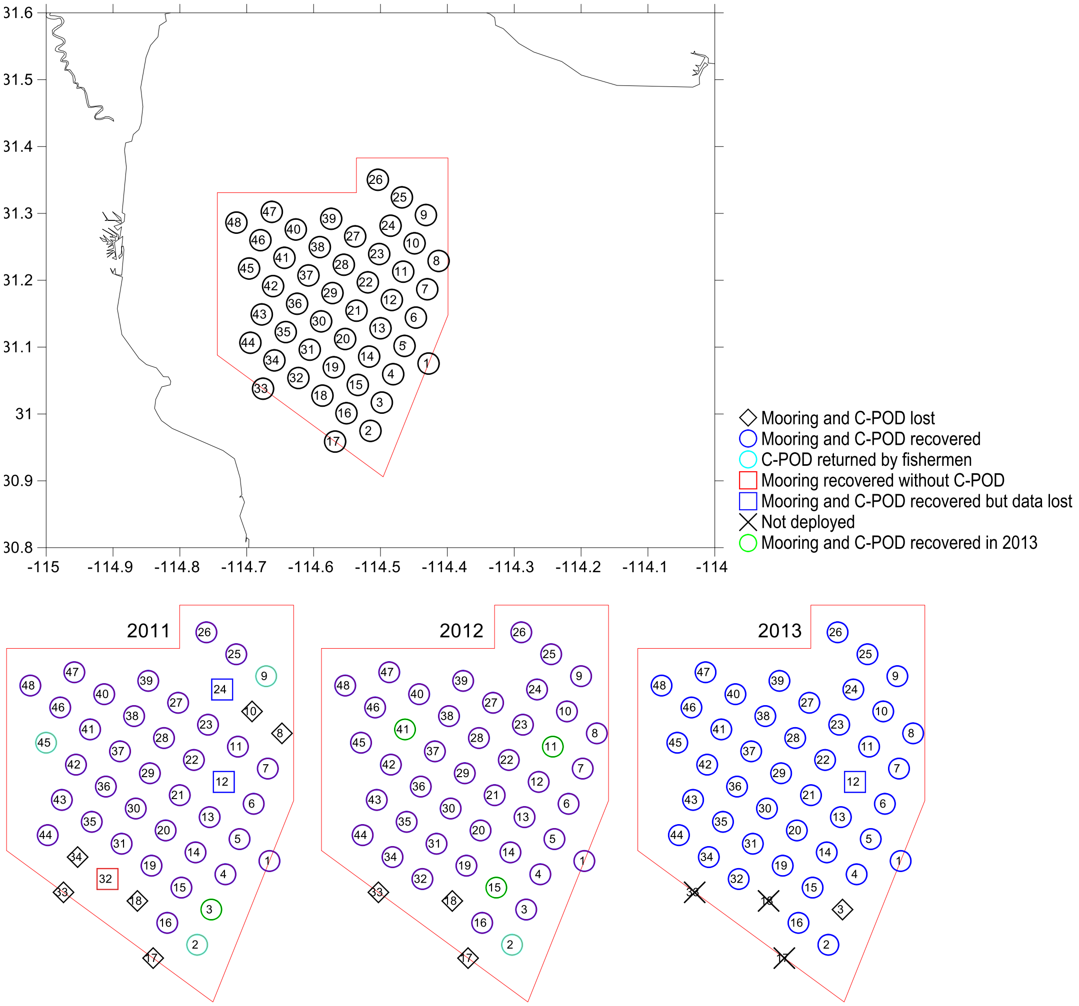
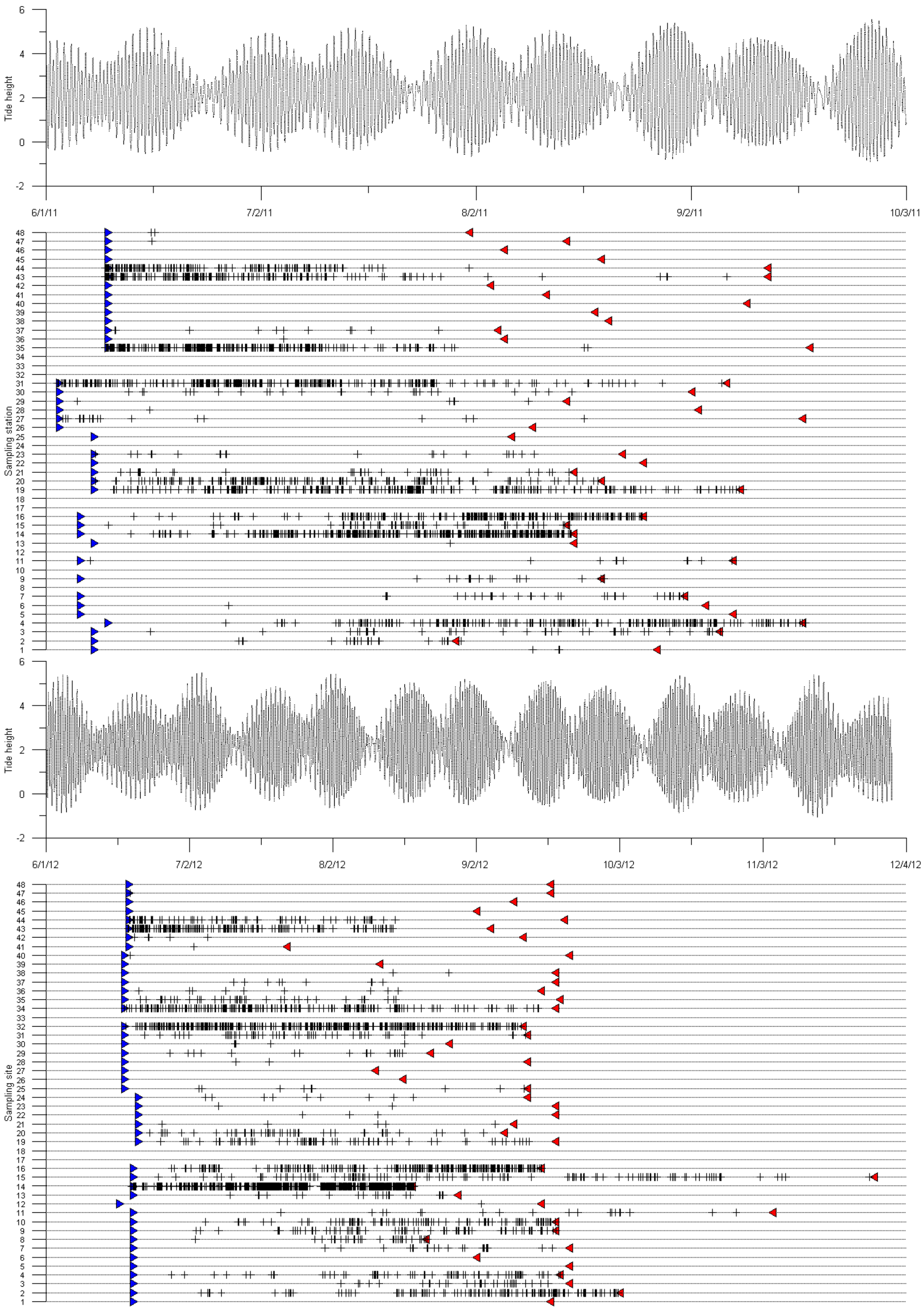


Figure 20. Position of the sampling sites inside the Vaquita Refuge (upper map, numbered circles). Below are the results of moorings and acoustic detectors deployed in 2011, 2012, and 2013. C-PODs were not deployed at sites 17, 18, and 33 in 2013 (X's). The CPOD at site 32 in 2011 was recovered June 25, 2013 and data were included in this analysis. Circles indicate sites where data are available, diamonds indicate all equipment lost at that site, and squares indicate sites where the mooring was recovered without the detector or the detector was recovered without any data.


Tide height
6
4
2
0
-2
6/1/11
7/2/11
8/2/11
9/2/11
10/3/11
Sampling station
48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
Tide height
6
4
2
0
-2
6/1/12
7/2/12
8/2/12
9/2/12
10/3/12
11/3/12
12/4/12
Sampling site
48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

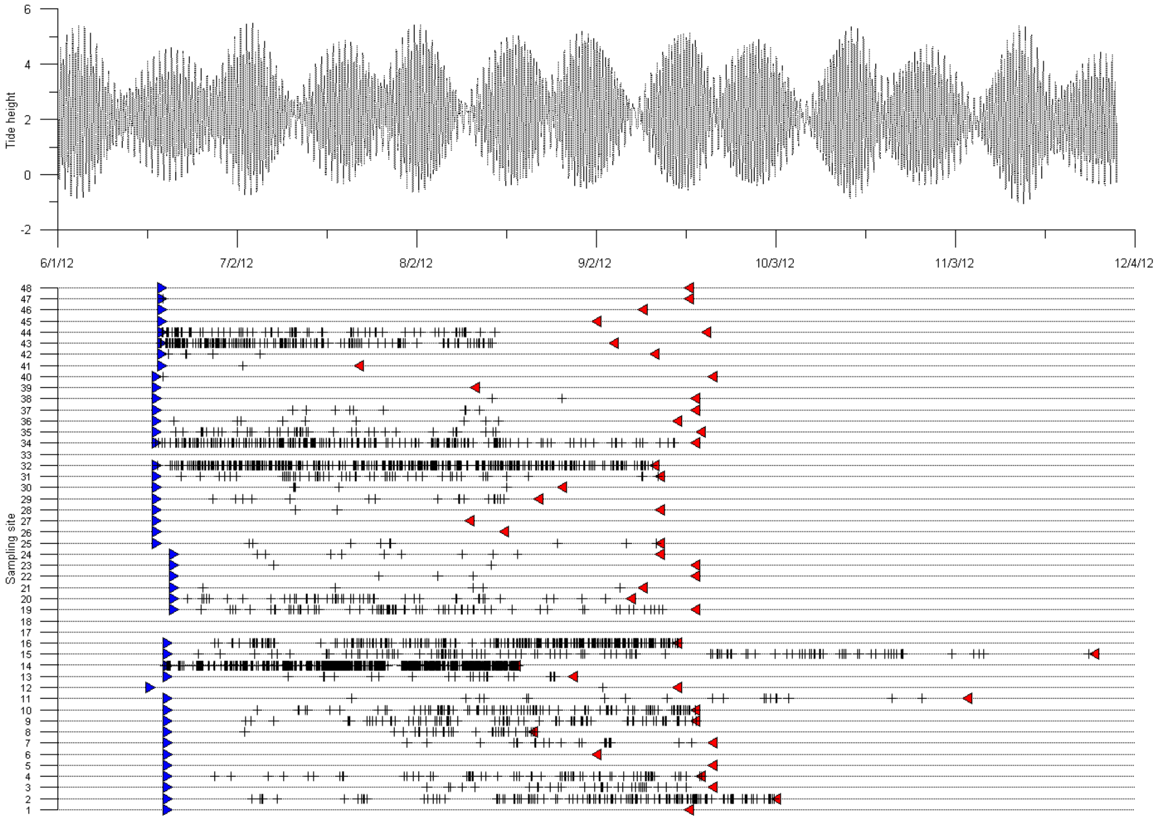


Figure 21. Detection Positive Minutes (DPM´s represented by crosses) (2011-2013) for every available sampling station. Tide heights for San Felipe (closest town to vaquita distribution area) are shown in the top panel for June – September, except for 2012 where period is extended because data were available through November for sites 11 and 15 (detectors recovered on 2013). In the lower panel blue triangles indicate the first sampling day and red triangles the last sampling day. C-PODs were turned throughout this period.

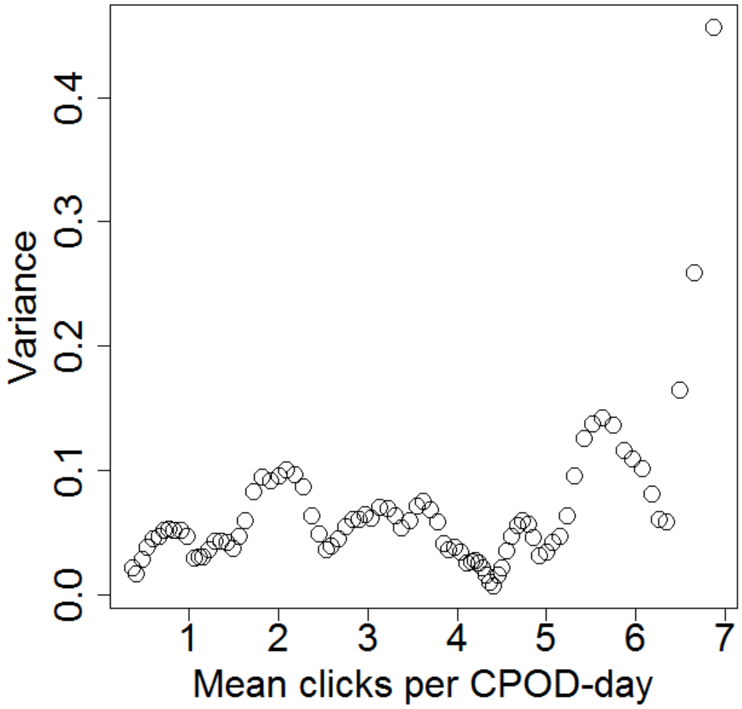


Figure 22. Variance and mean of log-transformed data, i.e., var[log(x_k+1)] and mean[log(x_k+1)], where x_k is the mean number of clicks per day for an individual CPOD location in a particular year (128 unique values) using data from the core sampling period. Each point represents the mean and variance of 10 ordered values (e.g., left-most point is mean and variance of the 10 lowest x_k values; next point is mean and variance of 2nd lowest to 11th lowest x_k,, etc.). Moving window approach results in serial autocorrelation in the variance values, but overall the variance is relatively constant with respect to the mean on the log scale (apart from a few outliers), justifying use of the Gaussian spatial model (constant variance assumption) of the log-transformed data.