UNIVERSITAT DE BARCELONA

DEPARTAMENTO DE BIOLOGIA ANIMAL

Estudio poblacional del visón americano (*Mustela vison*) en Cataluña: ecología y control de una especie invasora

Population study of the American mink (*Mustela vison*) in Catalonia: ecology and control of an invasive species

Yolanda Melero Cavero

Programa de doctorado de Zoología, bienio 2002-2004

VºBº

Dr. Joaquim Gosàlbez Noguera

VºBº

Dr. Santiago Palazón Miñano

ÍNDICE

AGRADECIMIENTOS

Esta tesis esta dedicada a todos aquellos que de alguna u otra forma han hecho posible su realización ayudándome ya sea en el ámbito científico o en el personal durante estos cuatro años de dedicación. Por ello, y en primer lugar, quiero agradecerles a mis dos supervisores Joaquim Gosàlbez y Santiago Palazón la confianza que desde el principio depositaron en mí.

A Joaquim, quisiera agradecerle el brindarme la oportunidad de compartir su sabiduría conmigo, su racionalidad en perfecta combinación con la emotividad, su honestidad, su comprensión y sobre todo su nobleza y criterio de justicia, lo que le ha convertido en mi modelo de persona a imitar. Agradecerle también toda su preocupación y dedicación hacia mí, sus consejos (que ya son doctrinas) que tanto me han ayudado a madurar y crecer en estos años, así como su apoyo y comprensión en cualquier momento.

A Santi, agradecerle el haberme traspasado todos sus conocimientos sobre la materia, y el hacerlo con toda la humildad y naturalidad del mundo. Le quiero agradecer todo aquello que hace tanto por mí como por muchos otros, de forma totalmente desinteresada; siendo un ejemplo de honestidad, naturalidad, confianza y especialmente de bondad y accesibilidad. Agradecerle también su preocupación y su apoyo en los momentos más difíciles.

Con toda sinceridad, es un honor trabajar con vosotros y gozar de vuestra amistad.

En segundo lugar, quisiera agradecer el apoyo a mi familia: mis padres y mi hermana. A mi padre por sacrificarse tanto por sus hijas y por esos momentos de expresividad que tanto le cuestan pero tanto se agradecen. A mi madre por su extrema paciencia, especialmente durante mi adolescencia y en mis años difíciles; por protegerme y cuidarme siempre; por hacer de mí una prioridad de su vida y ante todo por ser una madre tan cariñosa y atenta, una madre incomparable que ha conseguido una familia segura, solvente, independiente y a la vez unida. A mi hermana, por ser no solo la hermana perfecta si no también la amiga y psicóloga perfecta; por ser parte de mí y haber sido y ser siempre un modelo para mí, su clon; por sus consejos, sus broncas y ante todo su cariño incondicional.

En tercer lugar, me gustaría agradecer a todas aquellas personas especiales de mi vida el dejarme formar parte de su día a día.

A Vasco, agradecerle su buen gusto estético que ha dado lugar entre otras cosas al diseño de la portada de esta tesis. Pero ante todo quiero agradecerle todo su apoyo y su cariño, su indiscutible nobleza y su alto concepto de la amistad. Gracias por la ayuda en los malos momentos que se transformaron en buenos al tenerle a mi lado. En sus propias palabras: es un placer compartir lo cotidiano contigo.

A Nacho, gracias eternamente por la extrema paciencia leyendo y corrigiendo toda la tesis. Pero sobre todo le agradezco su inteligencia, su naturalidad, su cariño y su saber acoger. Sentirse a gusto contigo es la cosa más natural del mundo.

A Manu, gracias primero por su alegría que tanto se nota en falta, por su espontaneidad y simpatía, su madurez, su capacidad empática y por supuesto, por sus correciones idiomáticas. Lo cotidiano contigo se transforma en interesante.

A Marcos, le agradezco las charlas, la alegría, el esoterismo centrado, la paciencia y la vida que transmite. Compartir una amistad contigo es una dulzura que espero sea eterna.

A Jose quiero agradecerle todo el cariño que da, cargado de expresividad, atención, naturalidad y dulzura. Una recarga de afecto en cualquier momento que crea adicción.

A Santi, su accesibilidad, su predisposición a ofrecer ayuda y su sinceridad.

A Jor, nuestra complicidad, su apoyo, su cariño, las charlas, su ayuda en cualquier momento y su comprensión. Una amistad sólida creada a fuego lento

A los chicos: Marcelo, Diego, Gastón y David el ser por orden: paciente e inteligente; vivo y energético; centrado y calmado; dinámico e interesante.

A Arnau, por sus *advices,* por estos casi 5 años de amistad, por parecerse un poco a mí en algunas cosas y por compartir sus momentos conmigo. Un ejemplo increíble de madurez, racionalidad, nobleza y dinamismo.

A Eva, por nuestras charlas eternas y nuestra conexión y complicidad desde el principio. Una vibración maestra encontrada inesperadamente.

A Elena Rafart, por ser mi cargador de energía positiva personal, agradecerle la alegría y entusiasmo que derrocha con la gente que la merece y por su cariño. Una amistad plutónica.

A Joana, por encontrar en ella no sólo una excelente compañera de trabajo sino también una amiga increíble.

A Frederic, agradecerle el cumplir mi sueño de tener un amigo que es un fondo de sabiduria, por transmitirme sus conocimientos, por su cariño y especialmente por mostrarme su mejor cualidad: la bondad. Agradezco enormemente esa casualidad que me hizo reencontrarte y redescubrirte.

Por supuesto, a Maria, mi niña que ya forma parte de la familia, y a Héctor por todos estos años de magnífica amistad que con seguridad continuarán.

A Mónica por su paciencia, por todos los buenos momentos y por ser la persona del departamento que más me ha apoyado. Gracias también a Helena por su confianza y a Massimo por compartir conmigo las largas horas de despacho con tanto humor, simpatía y entusiasmo.

A Javi quisiera agradecerle su increíble paciencia y su ayuda en cualquier momento de crisis informática y no informática.

Asimismo, quiero dar las gracias a todas aquellas personas que me han ayudado en la elaboración del trabajo de campo. A Pep, el forestal, le agradezco enormemente su predisposición, accesibilidad y especialmente su amabilidad y sus charlas. A Albert, todo el esfuerzo de trabajo dedicado en mi estudio sin el cual no habría sido posible llevar a cabo con efectividad todo el trabajo de campo. Al *Departament de Medi Ambient* el material prestado para el estudio, y los buenos momentos con la gente de Fauna. A Jordi Ruiz-Olmo su interés y sus consejos que siempre son útiles y pragmáticos. Al centro de recuperación de animales de Torreferrusa y toda la gente que trabaja allí, en especial a Joan, a Pedro, y a Rafa.

Quisiera agradecer enormemente a aquellos investigadores que me acogieron en sus laboratorios. En primer lugar a Tim Tinker y Alisha Kage, *thanks a lot for all your help and specially for your warm welcome and friendship. Also, to my friends Eileen, Bridget and Candince thanks for the great moments*. En Segundo lugar, a

Eloy Revilla por ser un genio sencillo, amistoso y accesible; y a los compañeros que encontré en la EBD, especialmente a Jolies (*thanks sweety*). *Volevo ringraziare a Laura Bonesi per il suo aiuto e la sua disponibilità*. Gracias a Irene y a Katjia y Kathrin (*grazie ragazza*) por ofrecerme su amistad y por los buenos momentos que me proporcionaron en Trieste.

A todos los compañeros del departamento de Biología Animal por los buenos momentos de estos años: Irene, Encarna, Ana, Rocío Moreno, Javi, Fran, Sergi, Raül, Marc, Mark, Juan Carlos, Laura, Antigoni y un largo etc.

Y por último, a todos aquellos a los que olvidé mencionar pero han sido importantes para mí.

Introducción

El visón americano (*Mustela vison* Schreber, 1777), es un mustélido de tamaño medio de 550-670 mm de longitud y 1.500-2.000 g de peso en el caso de los machos; y 500-550 mm y 1.000-1.500 g en el caso de las hembras (Stroganov, 1962; Ruiz-Olmo y Aguilar, 1995). La morfología de la especie refleja su carácter semiacuático, presentando un cuerpo alargado, patas cortas con cinco dedos, con uñas no retráctiles, provistos de pequeñas membranas interdigitales, pelaje fino e impermeable, cuello ancho y cráneo deprimido. El patrón de coloración natural es negro o marrón oscuro, pero debido a los cruces realizados en cautividad y a las demandas de coloraciones para la industria peletera puede presentar coloración gris-plateada, blanca, e incluso con distintos matices de marrón, azul, crema, blanco, gris y arena.

En relación a su taxonomía, el visón americano está compuesto por 15 subespecies: *aestuarina, aniakensis, eanergumenos*, *evagor, evergladensis, ingens, lacustris, letifera, lowii, lutensis, melampeplus, mink, nesolestes, vison y vulgivaga* (Banfield, 1974; Hall, 1981); si bien actualmente existe controversia sobre la veracidad de esta división y se aboga por una futura clasificación basada en estudios genéticos. El género *Mustela* incluye 16 especies distribuidas por Eurasia, América y el norte de África (Macdonald, 2001) y está incluido dentro de la familia Mustelidae, la más amplia y diversa dentro de las familias de mamíferos carnívoros (orden Carnivora). Existen 66 especies de mustélidos agrupados normalmente en 25 géneros y 6 subfamilias (Wozencraft, 1993). Estas subfamilias son: Mustelinae (comadrejas, turones, visones, martas, tairas y glotones), Lutrinae (nutrias), Melinae (tejones), Mellivorinae (ratel del Cabo), Taxidiinae (tejones americanos), y Mephitinae (mofetas). Algunos autores, elevan esta última subfamilia a categoría de familia Mephitidae (Macdonald, 2001).

La distribución original del visón americano se extiende por Canadá y Estados Unidos, exceptuando el Norte del Círculo Polar Ártico (Banfield, 1974; Linscombe *et al.*, 1982) y el Sur de Texas, Arizona, Nuevo México y California (Hall, 1981).

A finales del siglo XIX, el floreciente comercio de su piel condujo al inicio de la cría en cautividad en Norteamérica. Esta tendencia se trasladó posteriormente al viejo continente. De este modo, a principios del siglo XX, más concretamente a partir de 1920 y después de la Segunda guerra mundial, la especie empezó a introducirse y criarse en Europa y en la antigua Unión Soviética a través de las granjas peleteras y con fines comerciales (Vidal-Figueroa y Delibes, 1987; Smal 1988; Linn y Birks, 1989; Dunstone, 1993). Dichas granjas comenzaron su actividad en Francia y en Alemania en 1926 (Gerell, 1971), en Gran Bretaña en 1929 (Thompson, 1962), en Noruega, Suecia y Finlandia en 1928-1929 (Gerell, 1971), en Dinamarca alrededor de 1930 (Andersen, 1981), en Islandia en 1931 (Skirnisson, 1980), en Irlanda en 1951 y en Polonia en el período 1950-1960. En la Unión Soviética fue introducido y soltado por la propia administración entre 1933 y 1962 en unas 200 localidades de todo el territorio (Aliev y Sandersen, 1970). En los Países Bajos, Hungría, Bulgaria, Austria, Suiza, Italia y Portugal no está determinada la fecha de introducción. Tanto debido a fugas accidentales como debido a sueltas deliberadas, se han ido formando poblaciones estables en numerosos países (Gerell, 1971; Maizeret, 1990; Dunstone, 1993). Actualmente, el visón americano se halla extendido en Austria, en la antigua Unión Soviética, en Argentina y Chile; y en Europa en la República Checa, en Eslovaquia y en casi la totalidad de Islandia, Irlanda, Suecia, Noruega, Finlandia, Dinamarca, Países Bajos y Gran Bretaña, y en algunas zonas de Francia, Alemania, España y Portugal (Bonesi y Palazón, 2007) (Figura 1).

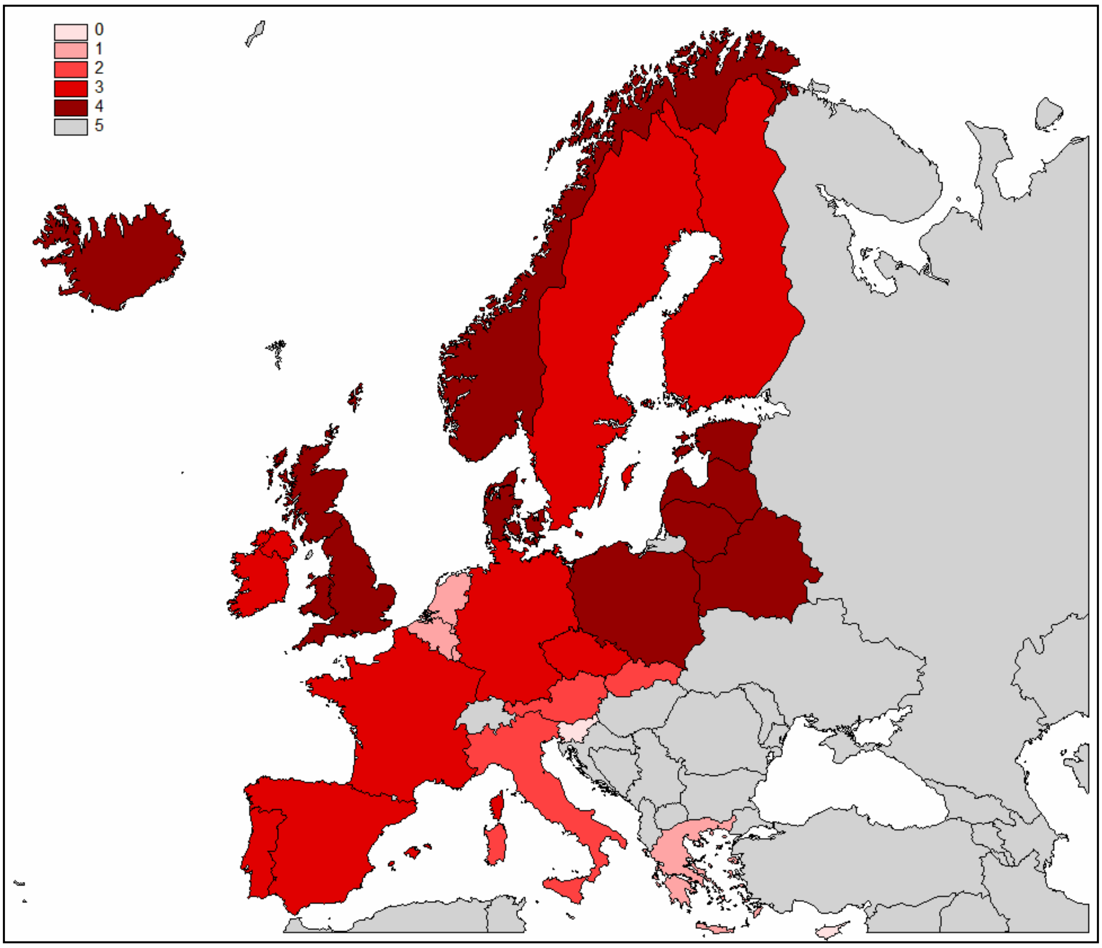


Figura 1: Presencia del visón americano en los países europeos. 0 = ausencia; 1 = encuentros esporádicos, sin confirmación de poblaciones asentadas; 2 = poblaciones asentadas en algunas áreas; 3 = distribuido en <50% del territorio; 4 = distribuido en >50% del territorio; 5 = estatus desconocido.

En España, el visón americano fue introducido durante los últimos años de la década de los 50s (Bravo y Bueno, 1992). Inicialmente en Segovia (1958) y Pontevedra (1959), y posteriormente en Cataluña, Cantabria, Ávila, Madrid y Teruel (Ruiz-Olmo, 1987; Vidal-Figueroa y Delibes, 1987; Bravo y Bueno, 1990; Ruiz-Olmo *et al.*, 1997; Palazón y Ruiz-Olmo, 1998). Sus escapes causados por fugas esporádicas masivas (incendios forestales, huracanes y apertura de instalaciones debido a acciones de activistas o abandono de instalaciones por sus propietarios) y por fugas constantes de algunos ejemplares, permitieron su expansión y colonización en los ecosistemas ibéricos formando poblaciones silvestres actualmente perfectamente aclimatadas (Vidal-Figueroa y Delibes, 1987).

La primera cita como especie de la fauna fluvial en la Península Ibérica se debe a Delibes y Amores (1978). Según datos de la bibliografía, a finales de la década de los 80s existían tres núcleos poblacionales ubicados en Galicia (Vidal-Figueroa y Delibes, 1987), en Cataluña (Ruiz-Olmo, 1987) y en el Sistema Central (Bueno y Bravo, 1990). Actualmente se han detectado dos o tres núcleos perfectamente aclimatados en Galicia, dos o tres en el País Vasco, uno en el centro de España (desde Extremadura hasta Burgos y Soria), uno en Cataluña y otro en Teruel-Castellón (Figura 2) (Delibes, 1983; Ruiz-Olmo, 1987; Vidal-Figueroa y Delibes, 1987; Bravo y Bueno, 1992; Ruiz-Olmo *et al.*, 1997; Palazón y Ruiz-Olmo, 1998; Ruiz-Olmo *et al.*, 1999). En 1993 la especie se extendía por un total de 183 cuadrículas U.T.M. 10 x 10 km (18.300 km^2) (Palazón y Ruiz-Olmo, 1998).

La presencia de visón americano en Cataluña fue detectada por primera vez en 1982 (Ruiz-Olmo, 1985). Su origen procede de dos granjas peleteras, actualmente inactivas, ubicadas en los términos municipales de Viladrau (Gerona) y Taradell (Barcelona). En la primera granja fueron sucediéndose fugas constantes de ejemplares accediendo a un río situado junto a la granja (Riera Major); sin embargo, el número de ejemplares fugados debió ser relativamente bajo (Palazón y Ruiz-Olmo, 1998). En la segunda, un incendio forestal ocurrido en 1983 permitió una fuga masiva de visones. En esos momentos, la granja contaba con 3.000-4.000 hembras y probablemente muchos ejemplares consiguieron sobrevivir. Posteriormente, durante su reconstrucción en 1983, se escaparon 10 hembras gestantes (Ruiz-Olmo, 1987). Actualmente existe una única granja de visón americano en el término municipal de Ullastret (Girona), que si bien poseen buenas medidas de seguridad no dejan de representar un peligro potencial.

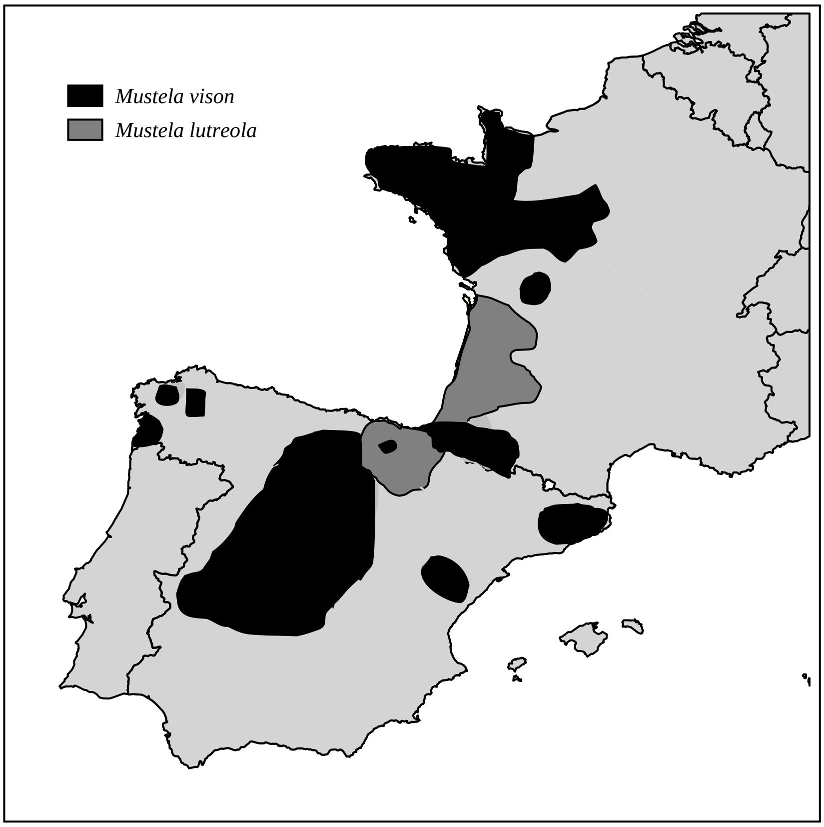


Figura 2. Distribución del visón americano, *Mustela vison* y del visón europeo, *Mustela lutreola*, en España. Se muestra también las poblaciones francesas más cercanas a la Península Ibérica.

En 1985 la población de visón americano en Cataluña ocupaba 12 cuadriculas UTM de 10 x 10 km (Ruiz-Olmo, 1987), y en 1992 ya ocupaba 35 cuadrículas (Palazón y Ruiz-Olmo, 1997). En la actualidad la población se distribuye por todas las comarcas de las provincias de Barcelona (excepto el Alt Penedès) y de Girona, desde la costa hasta las zonas casi pirenaicas y en Lleida se ha detectado su presencia en algunos afluentes del río Segre (comarcas de El Solsonès y La Segarra). La expansión de estas poblaciones se dirige principalmente hacia el norte, y con menor velocidad hacia el sur y hacia el oeste (Palazón y Ruiz-Olmo, 1997).

Tanto las poblaciones nativas como las introducidas se encuentran asociadas normalmente a bosques y a zonas de arbustos o matorrales adyacentes a habitats acuáticos, evitando generalmente áreas abiertas o expuestas (Dunstone, 1993). Mason y Macdonald (1983) detectaron una fuerte correlación entre la densidad de arbustos en la línea de ribera y la presencia de visón americano. La selección del hábitat en los visones americanos parece estar condicionada principalmente por la disponibilidad de presas y de madrigueras (Gerell, 1970; Birks y Linn, 1982; Dunstone, 1993, Halliwell y Macdonald, 1996).

El visón americano presenta un comportamiento territorial a lo largo del año exceptuando a los machos en la época de apareamiento, cuando abandonan sus territorios en busca de hembras. Dicha época de apareamiento varía en función de la latitud y del fotoperíodo (Sundqvist *et al.,* 1989) siendo más tardía a medida que nos acercamos al ecuador. Las hembras de visón americano presentan una gestación con implantación diferida del óvulo en el útero, lo cual permite dividir el periodo de gestación en dos etapas. La primera, previa a la implantación, oscila entre 13-15 días; la segunda, la del desarrollo embrionario, oscila entre 28-33 días. En total la gestación puede durar entre 39 y 76 días con una media de 51 días (Enders, 1952). Esta estrategia evolutiva permite adaptar el ciclo reproductivo de las poblaciones a un periodo de máxima disponibilidad de presas. El tamaño habitual de la camada oscila entre 6-7 embriones, si bien se pueden llegar a implantar hasta 12 (Chanin, 1983). Los partos se producen entre abril-mayo con una media de 4 a 6 crías por camada, las cuales son destetadas a las 4 semanas y abren los ojos a los 30 días (juveniles) (Dunstone, 1993). Aproximadamente, 4-5 crías superan la mortalidad post-natal (subadultos) (Eagle y Whitman, 1987) y se independizan de la madre entre agosto y septiembre. Se inicia así la dispersión en busca de nuevos territorios y refugios para el invierno (Chanin, 1983; Ireland, 1990; Dunstone, 1993). A los 10 meses de edad, todos los individuos subadultos adquieren la madurez sexual y presentan dimensiones de adulto, si bien los machos pueden seguir aumentando de peso hasta su segundo año de edad (Eagle y Whitman, 1987).

Aunque el visón americano presenta hábitos preferentemente nocturnos, es capaz de modificar su comportamiento circadiano en función de las condiciones medioambientales y especialmente en función de la disponibilidad de presas. Como carnívoro presenta una dieta generalista basada en micromamíferos, peces, invertebrados, aves y anfibios (Gerell, 1968; Chanin y Linn, 1980; Birks y Dunstone, 1984). Su efecto como depredador exótico puede reducir, y localmente exterminar, algunas especies protegidas que potencialmente forman parte de su dieta como el cangrejo de río (*Austropotamobius pallipes*) y el desmán ibérico (*Galemys pyrenaicus*) (Palazón y Ruiz-Olmo, 1998; Palomo y Gisbert, 2002), la rata de agua en España (*Arvicola sapidus*) o la rata de agua en Inglaterra (*Arvicola terrestris*) (Carter y Bright, 2003). La presencia del visón americano también afecta a la red de depredadores alóctonos pudiendo provocar un desequilibrio en la estructura poblacional de otros depredadores semiacuáticos como el turón (*Mustela putorius*), el visón europeo (*Mustela lutreola)* y la nutria (*Lutra lutra*) a causa de la competencia y de la enfermedad Aleutiana del Visón, producida por un parvovirus del cual es vector. De hecho, el visón americano se considera como una de las causas de la rarefacción y desaparición del autóctono visón europeo (Mason y Macdonald, 1983; Mañas *et al.*, 2001; Sidorovich y Macdonald, 2001). Ambas especies explotan un nicho ecológico muy similar y existe una ventaja interespecifica a favor del americano que suele acabar con en un desplazamiento del visón europeo (Sidorovich *et al.*, 2000). Este sesgo a favor del visón americano viene dado por su mayor tamaño, agresividad, mayor plasticidad ecológica y mayor capacidad de reproducción.

En España, las distribuciones de las dos especies no coincidieron hasta 1990-1992, momento en que se instalaron las primeras granjas de visón americano en el País

Vasco. La presencia de estas granjas favoreció el asentamiento de poblaciones de visón americano en las zonas de distribución del visón europeo (Palazón y Ruiz-Olmo, 1997). De hecho, actualmente la población española del visón europeo se encuentra prácticamente rodeada de poblaciones de visón americano (Figura 2) (Palazón *et al.*, 2003).

El mayor peligro de la expansión de la población catalana de visón americano reside en su expansión hacia el Sur, donde llegaría a conectar con el río Ebro y hacia el oeste. La expansión hacia el norte podría implicar el contacto con el desmán ibérico (*Galemys pyrenaicus*) (datos del Departament de Medi Ambient i Habitatge, Generalitat Catalana; Palazón, 2006). La expansión por el este está frenada por el mar. Sin embargo, la expansión sur y/u oeste supone una amenaza para las poblaciones de visón europeo dado que supondría el contacto entre las dos especies por la parte este de la población del visón europeo. El control de las poblaciones de visón americano como acción preventiva y de conservación del visón europeo es una de las secciones más importantes en el marco del proyecto LIFE para la conservación del visón europeo (*European Life Programs*: 02MNAT/8604, 00NAT/E/7299, 00NAT/E/7335 y 00NAT/E/7331 2001-2008; MMA 2006). Dicho programa se lleva realizando desde 2002 centrándose en el trampeo del visón americano para el control de su expansión y en el estudio de sus poblaciones para incrementar la eficacia del trampeo y aportar nuevas pautas y metodologías.

Las posibles opciones barajadas para el control incluyen el aumento de la mortalidad de los individuos, la manipulación del hábitat y el control a través de depredadores/competidores nativos. Existe la posibilidad de métodos basados en virus o inmunocontracepción pero la especificidad no es suficientemente alta como para evitar consecuencias sobre otras especies autóctonas (Tuyttens y Macdonald, 1998a, 1998b, 2000) y el coste económico es demasiado elevado. Actualmente, la opción más práctica y factible de control en la actualidad es el trampeo (Macdonald *et al.*, 2000), combinado con la monitorización de las poblaciones para conocer su estado y dinámica poblacional. No hay duda de que el control del visón americano en España es una meta difícil de alcanzar, y que implica un elevado coste económico y un gran esfuerzo humano. Por lo tanto, es importante la creación de estrategias eficaces y la identificación de áreas de control preferente. Asimismo, el control de visón americano basado en su exterminación no deja de ser un problema ético que debería limitarse hasta donde sea necesario y efectivo.

Tanto el declive en Norteamérica como la problemática de especie invasora en Europa, Asia y Sudamérica han provocado en los últimos tiempos un auge en el estudio de esta especie. Mientras que en Norteamérica los estudios se centran en su conservación (Humphrey y Zenn, 1982; Arnold y Fritzell, 1990; Ben-David *et al.*, 1995; Ben-David, 1997), la selección del hábitat (Loukmas y Halbrook, 2001) y en el efecto de la contaminación sobre su supervivencia y reproducción (Aulerich *et al.*, 1973 y 1990; Aulerich y Ringer, 1977; Kihlström *et al.*, 1992), en Sudamérica (Previtali *et al.*, 1998), y en Europa (Bonesi y Palazón, 2007) tienen como finalidad el control y la erradicación de las poblaciones establecidas. La diversidad de estudios sobre visón americano en Europa abarcan desde la distribución general de la especie en todo el continente o en determinados países (Gerell, 1967; Aliev y Sanderson, 1970; Akande, 1972; Palazón y Ruiz-Olmo, 1997), la dinámica poblacional (Smal, 1991, Bonesi *et al.*, 2006), el comportamiento ecológico (Birks y Linn, 1982; Dunstone y Birks, 1983; Birks y Dunstone, 1985; Lodé, 1993 y 2001; Dunstone, 1993; Palazón y Ruiz-Olmo, 1992; Yamaguchi y Macdonald, 2003), la selección del hábitat (Bonesi *et al.*, 2004; Yamaguchi *et al.*, 2003), la dieta y la depredación sobre especies protegidas (Gerell, 1967 y 1968; Chanin y Linn, 1980; Birks y Dunstone, 1984; Ward *et al.*, 1986; Brzezinski y Zurowski, 1992; Bueno, 1994; Halliwell y Macdonald, 1996; Macdonald, 2002; Boensi *et al.*, 2004), o la competencia con otros depredadores que ocupan similares nichos ecológicos, como el visón europeo (Maran y Henttonen, 1995; Palazón y Ruiz-Olmo, 1997), el turón (Lodé, 1993) y la nutria (Erlinge, 1969 y 1972; Jenkins y Harper, 1980; Wise *et al.*, 1981).

OBJETIVOS

El objetivo principal de este estudio es incrementar el conocimiento sobre la población de visón americano en Cataluña proporcionando así una base sólida para crear estrategias eficaces para su control. Los objetivos específicos del estudio son:

1. Analizar la morfología de la población para valorar si existen variaciones como respuesta al proceso de aclimatación y adaptación a los nuevos ecosistemas y a la presión por competición.
2. Analizar la ecología trófica de la población y los posibles solapamientos de nicho trófico con otros depredadores presentes en el área.
3. Determinar la selección de hábitat dentro del territorio individual.
4. Determinar el tamaño del territorio individual, los posibles solapamientos y los factores implicados en el tamaño del territorio.
5. Describir sus patrones de actividad y los posibles factores que afectan dicho comportamiento.
6. Comprobar la eficacia de las campañas de trampeo y control mediante la comparación de la dinámica poblacional de núcleos poblacionales sometidos a un proceso de control *versus* poblaciones no controladas.
7. Predecir la distribución potencial de la especie en Cataluña basada en sus requerimientos ambientales.
8. Establecer y proporcionar un protocolo de muestreo de visón americano apropiado para la determinación de la presencia o ausencia de la especie.

Sobre la consecución de estos objetivos, se han realizado seis artículos científicos que se corresponden con los seis capítulos que, en conjunto, estructuran la presente memória. El título de los artículos que constituyen el estudio son los siguientes:

- Morphological adaptation of an invasive American mink population in Mediterranean areas of Spain.
- Feeding habits of three sympatric mammals in a riparian habitat in NE Spain: the American mink, the spotted genet, and the Eurasian otter.
- Space use and habitat preferences of the invasive American mink in a Mediterranean area.
- Patterns of activity in an invading Mediterranean population of American mink (*Mustela vison*).
- Growth of culled and non culled American mink populations in Northeast Spain and their potential distribution: are culling campaigns effective?
- Evaluating sign surveys as a way to monitor the American mink in Spain

METODOLOGÍA

La metodología empleada en la realización del presente estudio se ha dividió en los siguientes apartados:

ÁREA DE ESTUDIO

Para la realización del estudio se seleccionó un tramo del río Llobregat y de su afluente, la riera Gavarresa, localizados ambos en la comarca de El Bages, en la Cataluña central. La zona de estudio se dividió en dos áreas: el área central y el área adyacente. El área central se localiza entre las longitudes 1º 53' 34'' y 1º 56' 50'' y las latitudes 41º 49' 2'' y 41º 46' 23'', con 11 km de tramos fluviales (6 km del río Llobregat y 5 de la riera Gavarresa) (Figura 3). El área adyacente se localiza entre las longitudes 1º 46' 55'' y 2º 2' 19', y las latitudes 41º 52' 60'' y 41º 42' 38'', con 45 km de tramos fluviales (15 km aguas arriba y 15 km aguas abajo de los límites del río Llobregat en el área central, y 15 km aguas arriba del límite de la riera Gavarresa en el área central).

En la zona de estudio, el río Llobregat mantiene una anchura aproximada de unos 12-16 m. Por su parte, en la riera Gavarresa, la anchura media del tramo estudiado se encuentra entre los 5 y 6 m. En ambos casos la calidad del agua es bastante baja siendo la contaminación orgánica consecuencia de su proximidad a áreas urbanas, agrícolas e industriales. No obstante, cabe comentar que se considera que durante los últimos 15 años el nivel de contaminación ha disminuido gracias a la construcción de varias depuradoras.

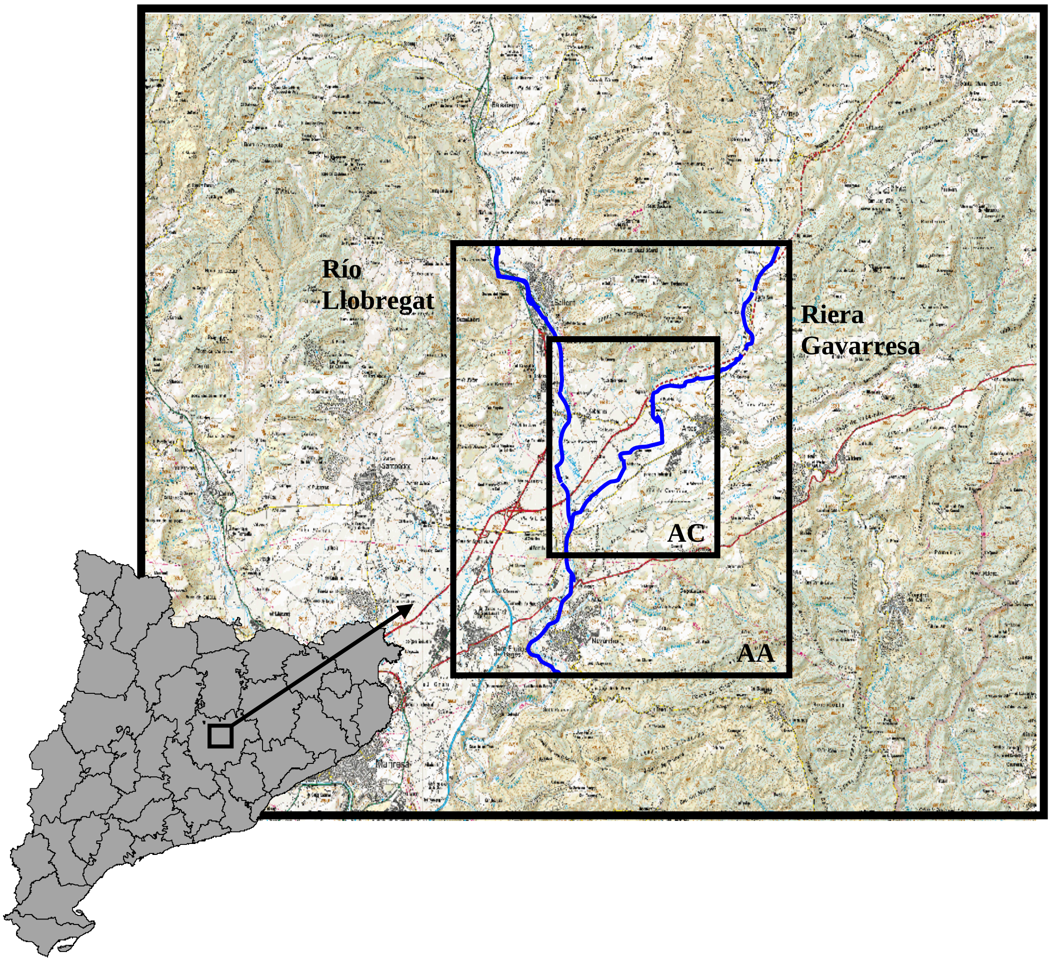


Figura 3. Localización del área de estudio central (AC) y del área de estudio adyacente (AA).

Asociados a estos cursos fluviales existe un bosque de ribera caracterizado por una vegetación mayoritariamente helofítica donde la caña (*Arundo donax*), la espadaña (*Typha latifolia*), el carrizo (*Phragmites communis*) y el junco (*Juncus* spp.) son las especies más abundantes. La vegetación arbustiva está principalmente formada por zarza (*Rubus ulmifolius*), además de otras especies como el boj (*Buxus sempervirens*), el cornejo (*Cornus sanguinea*) y el sauco (*Sambucus nigra*). En primavera y verano, la cobertura herbácea adquiere una gran importancia, con la presencia de la ortiga (*Urtica dioica*), diversas especies de menta (*Mentha* spp.), el hinojo (*Foeniculum vulgare*) y la hiedra (*Hedera helix*). En otoño e invierno sólo permanece la cobertura propiamente herbácea a ras de suelo. En algunos tramos se encuentran pequeñas masas de chopo (*Populus alba*), sauces (*Salix* spp.) y en menor medida pino piñonero (*Pinus pinea*), pino albar (*Pinus halepensis*), olmo (*Ulmus minor*) y fresno (*Fraxinus angustifolia*). Las lluvias de otoño provocan una disminución en la presencia de vegetación debido al efecto de arrastre especialmente acusado en las orillas caracterizadas por su facilidad para inundarse. El tipo de vegetación descrita permite una abundancia de refugios potenciales para el visón americano sobre todo debido a la predominancia de los niveles helofítico y arbustivo. El entorno está formado por cultivos de secano, fundamentalmente viña (*Vitis vinifera*) o cereales diversos, pequeños cultivos particulares de regadío, industrias como el polígono industrial del municipio de Cabrianes y carreteras, salpicados de masas de bosque natural y prados.

En el área de estudio existen otras especies de fauna que pueden ser tanto competidoras como depredadoras potenciales del visón americano, como la nutria (*Lutra lutra*), la jineta (*Genetta genetta*), la garduña (*Martes foina*), el tejón (*Meles meles*), el zorro (*Vulpes vulpes*) y los gatos y perros asilvestrados, que son muy abundantes. En cuanto a posibles presas destacan el cangrejo de río americano (*Procambarus clarkii*), los roedores (*Mus musculus* y *Apodemus sylvaticus*), los insectívoros (*Crocidura russula*), los peces (*Salmo trutta*, *Barbus graellsii*, *Barbus haasi*, *Chondrostoma toxostoma*, *Cyprinus carpio*, *Squalius cephalus*, *Scardinius erythrophthalmus*) (Doadrio, 2001), las aves (*Anas plathyrynchos*, *Gallinula chloropus*, *Erithacus rubecola*, *Phylloscopus collybita*, *Silvia atricapilla*, *Turdus philomelos*, *Motacilla alba*, *Cettia cetti*, *Fringilla coelebs*) y, en menor medida, anfibios (*Salamandra salamandra*, *Alytes obstetricans*, *Rana perezi*, *Pelobates cultripes*, *Pelodytes punctatus*, *Bufo bufo*), reptiles (*Testudo hermanni*, *Mauremys leprosa*, *Psammodromus algirus*, *Timon lepidus*, *Podarcis hispanica*, *Anguis fragilis*, *Malpolon monspessulanus*, *Elaphe scalaris*, *Natrix maura*) (Llorente *et al.*, 1995) e insectos.

Fisiográficamente, la zona de estudio se ubica dentro de la región del Altiplano Central de Cataluña (Folch i Guillèn y Franquesa, 1984). La altitud de la zona oscila entre 160 y 350 m y las temperaturas medias anuales por meses oscilan entre una máxima de 25,7 ºC (agosto) y una mínima de 4,6 ºC (enero). La media de las temperaturas máximas por meses varía entre 34 ºC (agosto) y 10,3 ºC (febrero) y la media de las mínimas por meses entre 10,3 ºC (agosto) y -0,3 ºC (enero). Tanto el río Llobregat como sus afluentes se caracterizan por una fuerte oscilación anual del caudal hidrológico, consecuencia del carácter típico del clima mediterráneo con un régimen de precipitaciones irregular.

La unidad del paisaje vegetal pertenece a los altiplanos y cuencas centrales catalanas (territorio auso-segárrico), encontrándose la zona de estudio a medio camino de los relieves orientales (sector ausónico) y los relieves occidentales (sector segárrico). El dominio básico de vegetación es el encinar continental. La vegetación actual de esta zona está formada por bosques, matorrales, prados, vegetación helofítica y de ribera, vegetación ruderal y vegetación agrícola (Folch i Guillèn y Franquesa, 1984).

MUESTREO DE LOS VISONES

Para la realización del muestreo se utilizaron trampas-jaulas de reja de dimensiones 15 x 15 x 60 cm, de una sola abertura con un balancín que provoca el cierre de la puerta cuando el animal entra. Se colocaron un total de 6.216 trampas noche (2.352 en el área central y 3.864 en el área adyacente). Los muestreos se desarrollaron alternando 4 ciclos de 7 días consecutivos de muestreo con 7 de descanso entre octubre y diciembre de 2003 a 2005 y en enero de 2004. Las trampas se ubicaron en ambos márgenes del río, a una distancia máxima de 2-3 m de la orilla y separadas entre si por aproximadamente 250-300 m en el área central y 450-500 m en el área adyacente, en función de las condiciones del terreno. Como cebo se usaron huevos

de gallina y varios rastros de aceite frito desde el límite del agua hasta el interior de la trampa. Cada trampa se revisó diariamente por la mañana y repuesto el cebo cuando fue necesario. El rastro de aceite se reforzó cada tres o cuatro días.
Los datos obtenidos fueron registrados en fichas de muestreo con información de la fecha, identificación del animal (nueva captura o recaptura), número de la trampa de captura y localización UTM de la trampa (Anexo I).

MANIPULACIÓN Y MARCAJE DE LOS VISONES

Los animales, previa a su manipulación, se anestesiaron con una o varias dosis (según el estado nervioso del animal) de 0,15 ml de ketamina hidroclorada mezclada con 0,03 ml de metedomidina. El tiempo normal de espera hasta el efecto de la anestesia fue de entre 3 y 7 minutos. Después se procedió a la toma de parámetros biológicos y biométricos (peso, longitud total, longitud de la cola, longitud del pie posterior y longitud de la oreja), y al marcaje de los animales, siendo registrados todos estos datos en fichas individuales para cada animal (Anexo II).

El visón americano se pueden clasificar en tres clases de edad: juvenil (0-4 meses de edad, desde su nacimiento a finales de abril-principios de mayo, hasta finales de agosto), durante este tiempo permanecen con la madre; subadultos (5-8 meses de edad, entre septiembre y diciembre), cuando inician la dispersión; y adultos (más de 8 meses de edad, a partir de enero del siguiente año). Los animales capturados se agruparon por sexo y por edades en juveniles, subadultos y adultos dependiendo de la época de captura, del estado de la dentición, del estado sexual y de la longitud total y peso del animal. Debido al rápido crecimiento del visón, como ocurre en otras especies de pequeños mustélidos, la talla adulta se adquiere a los tres o cuatro meses. Los nacidos entre abril y mayo, en agosto-septiembre presentan el tamaño de adulto. El principal factor para su distribución por edades se basa en la época de captura y en el estado de la dentición. Durante el período comprendido entre abril y finales de agosto sólo existen ejemplares juveniles y adultos de años anteriores. Se catalogan como juveniles aquellos ejemplares que poseen dentición de leche o rastros de dientes de leche recientes, y cuya longitud total y longitud del cuerpo (sin cola) son menores a 550 mm en los machos y 350 mm en las hembras aproximadamente. En caso contrario se catalogan como adultos. Los ejemplares capturados entre septiembre y diciembre, se clasifican como subadultos (no maduros sexualmente) o adultos de años anteriores. Dado que en esta época los individuos adultos no están sexualmente activos, se hace imposible diferenciarlos de los subadultos basándose en la inmadurez sexual. Por lo tanto, la diferenciación entre ambos se basa en el estado de conservación de la dentición, del peso y de la longitud total (Maran y Robinson, 1996). Por último, todos los individuos capturados entre enero y finales de marzo se consideran adultos dado su estado de actividad sexual.

Para el marcaje de los ejemplares se emplearon simultáneamente grapas metálicas y chips magnéticos (o transponders). Las grapas llevan numeración de tres cifras y se colocaron en la parte superior de las orejas. Mediante un inyector se colocaron los transponders subcutáneos en la parte dorsal de los animales. El código se registró y leyó mediante un lector (Trovan Ltd.) con el fin de diferenciar las nuevas capturas de las recapturas.

Tras la manipulación del animal se respetó un tiempo mínimo de recuperación antes de la suelta, de 45 minutos, comprobando si el animal se encontraba totalmente despierto antes de la liberación. La suelta siempre se realizó en el punto de captura.

RADIOSEGUIMIENTO DE LOS VISONES

A varios ejemplares, del total capturados dentro del área central, se les colocó un collar emisor para realizar un seguimiento por radio con la finalidad de estudiar varios aspectos eco-etológicos de la especie. Los collares utilizados (Biotrack Ltd.) tenían frecuencias comprendidas entre 150.000 Mhz. y 151.000 Mhz. El peso de dichos collares era aproximadamente de 15 g, lo que representa menos del 3 % del peso de la hembra más pequeña capturada (520 g). La señal de los emisores se captó a través de un receptor modelo TR4 (Telonics Ltd.) y dos antenas (Telonics Ltd.), una multidireccional empleada para localizar al animal a larga distancia, y una segunda bidireccional que permitió una localización más precisa de la posición del animal. La localización UTM de los animales se tomó mediante receptor GPS (Garmin Ltd.). El radioseguimiento de los visones se realizó de forma directa, sin triangulación, ya que fue fácil localizar su posición a lo largo del río (Gerell, 1970; Birks y Linn, 1982; Ireland, 1990; Bonesi, 1996). Esta forma de localización disminuye el error producido mediante la triangulación. La localización se hizo lo más cercana posible a la posición del animal, a un mínimo de 2-3 m para evitar cualquier tipo de molestias y no influir en su comportamiento.

El radioseguimiento se realizó en el período octubre-febrero, hasta el día en que todos los emisores dejaron de funcionar o se perdió la señal de los visones. Los animales con emisor se siguieron diariamente en intervalos de 30-60 minutos. Los días en que no fue posible un seguimiento exhaustivo, se localizó a los ejemplares al menos una vez, salvo casos excepcionales en los que no se pudo obtener ninguna localización.

DESCRIPCIÓN DEL HÁBITAT

Los tramos fluviales del río Llobregat y la riera Gavarresa incluidos dentro del área central se dividieron en secciones de 100 m, registrándose en cada una de las secciones las siguientes variables del hábitat: profundidad y anchura del río en el tramo medio de cada sección, abundancia de vegetación y presencia de actividad humana. La profundidad se registró a 50 cm de cada orilla y en el centro del río. La vegetación se dividió en cuatro tipos: herbácea, helofítica, arbustiva y arbórea, las cuales se registraron en rangos de 0-5 según su abundancia en la sección correspondiente. La actividad humana se registró como ausente (0), agrícola (1) o industrial (2) siempre que estuviera presente en la ribera del río.

RECOLECCIÓN DE MUESTRAS DE DIETA

Se recolectaron un total de 444 excrementos de visón americano, 108 de nutria y 310 de jineta durante 2002-2005 tanto en el área central como en la adyacente. Tras la recolección e identificación, se procedió a su lavado mediante tamiz de 1 mm de malla y a la identificación de las presas consumidas. La identificación de las presas se realizó hasta el mínimo taxón posible empleando las claves de Gosàlbez (1987), Teerink (1991), Miranda y Escala (2002), Rage (1974) y mediante la comparación con colecciones personales.

PROSPECCIONES DE PRESENCIA/AUSENCIA

Las secciones de 100 m establecidas dentro del área central para la descripción del hábitat también sirvieron para la realización de prospecciones. Para ello se buscaron signos de visón americano (huellas o excrementos) en cada sección y dentro de una distancia máxima de 10 m desde ambas orillas del río.

La primera prospección se realizó en noviembre del 2004, en ella se eliminaron todos los signos de visón americano dado que era imposible de determinar su fecha. A partir de diciembre de 2004 y hasta abril de 2005, se realizaron prospecciones cada 20-30 días, con una duración de 2-3 días y tras 3 días de espera tras cualquier tormenta o lluvia. Todos los signos encontrados en cada prospección se eliminaron para evitar confusiones durante las siguientes prospecciones.

ANÁLISIS ESTADÍSTICOS

Todos los procedimientos estadísticos se han realizado mediante los programas estadísticos SAS 9.1 (SAS Institute Inc., Cary, NC, USA), SPSS versión 11.5 y 12 (SPSS Inc., Chicago, IL, USA) y Statgraphics 4.0 (StatPoint, Inc., Rendón, VG, USA). En el caso de cálculos matemáticos no estadísticos se han empleado los siguientes programas: ArcView 3.2 (Enviromental System Research Institute, Inc., USA) y GRASS 6.0.2RC4 (SSI/MPBA group, Italia) para cálculos de tamaños territorial, selección de hábitat, prospecciones y distribuciones; y el programa PRESENCE para cálculos de probabilidades de presencia/ausencia en base a las prospecciones.

Los programas y/o tests utilizados dependen de la naturaleza de los datos y del objetivo del análisis. Se han empleado modelos lineales generales mixtos (GLMM) para testar los posibles efectos de determinados factores sobre una o más variables dependientes. Los tests U Mann-Whitney y Kruskal Wallis se han empleado en los casos en que se testaba la hipótesis de igualdad ente dos muestras (U Mann-Whitney) o más (Kruskal Wallis) cuando los datos no seguían una distribución normal. Para observar diferencias entre porcentajes de dos o más categorías se ha empleado un test chi-cuadrado o una tabla de contingencia respectivamente. En casos de existir posibles correlaciones entre variables independientes, se ha utilizado un análisis de componentes principales (PCA) para discernir entre las variables necesarias y las prescindibles.

CAPÍTULOS

Morphological adaptation of an invasive American mink population in Mediterranean areas of Spain*

Yolanda Melero[1], Santiago Palazón[1,2] and Joaquim Gosàlbez[1]
[1]Department of Animal Biology (Vertebrates), University of Barcelona. Av. Diagonal 645, 08028 Barcelona, Spain.
[2]Directorate General for the Natural Environment, Deparment of Environment and Housing, Generalitat de Catalunya. Doctor Roux, 80, 08017 Barcelona, Spain.

E-mail addresses:
Yolanda Melero: melero@ub.edu
Santiago Palazón: santiago.palazon@gencat.net
Joaquim Gosàlbez: jgosalbez@ub.edu

Running head: Morphological adaptation of an invasive mink population

---

* Acta Zoologica, in press.

Abstract

Melero, Y., Palazón, S. and Gosàlbez, J. 2007. Morphological adaptation of an invasive American mink population in Mediterranean areas of Spain. – Acta Zoologica (Stockholm), accepted.

Yolanda Melero. Department of Animal Biology (Vertebrates), University of Barcelona. Av. Diagonal 645, 08028, Barcelona, Spain. E-mail: melero@ub.edu

In this work we studied the morphology of the American mink *Mustela vison* invasive population in Catalonia, Mediterranean Spain. Body weight, body length, tail length, hindfoot length and ear length were measured for four age-sex classes: subadult male (n = 17), subadult female (n = 16), adult male (n = 36) and adult female (n = 10). A General Lineal Mixed Model was used to test the effect of year, sex, age and age-sex interaction, on each parameter. The morphological results differed from other introduced populations due to their different origin and to their adaptation to different environments. Differences in sex and age were found, pointing to sexual dimorphism both in adults and subadults. The degree of dimorphism was lower than that of other populations, probably due to a lack of trophic niche separation between males and females since in the study area only small prey were available.

Key words: *Mustela vison*, morphology, sexual dimorphism, environmental adaptation, Mediterranean areas.

Introduction

The morphological characteristics of American mink populations vary regionally. For example, native North American populations were morphologically different among geographic areas (Dunstone 1993); populations in Ireland varied more than those in Britain (Dayan and Simberloff 1994); mink in Britain and Japan weighed less than those from Eastern Europe (Kondo *et al.* 1988; Birks and Dunstone 1991); and animals from Belarus had shorter skulls than those from Canada (Kruska and Sidorovich 2003).

Regional morphological differences may also reflect the varying degrees of sexual dimorphism among each area. Typically, the American mink is highly sexually dimorphic, with males reaching up to twice the size of females (Eagle and Whitman 1987; Kondo *et al.* 1988; Dunstone 1993; Macdonald and Strachan 1999; Thom *et al.* 2004). Sexual dimorphism may arise from competition (Brown and Lasiewski 1972; Hedrick and Temeles 1989), sexual selection (Erlinge 1979; Moors 1980) or divergent reproductive roles (Hedrick and Temeles 1989; Erlinge 1979; Moors 1980; Powell and Leonard 1983) and these factors may vary from one environment to another.

The species is native to North American environments. However, the American mink was introduced in Europe, Asia and South America during the 20th century (Vidal-Figueroa and Delibes 1987; Smal 1988; Linn and Birks 1989; Dunstone 1993).

This introduction resulted in an adaptation to new environments, and subsequent morphological changes (see Sidorovich *et al.* 1999, Sidorovich 2001). In Mediterranean areas, only a few escaped ranch mink were responsible for entire, isolated, populations. This type of situation may result in a bottle-neck effect on the populations due to limited genetic variation (Mayr, 1963). As a result, the new population may be distinctively different, both genetically and phenotypically, from the parent population from which it is derived.

Currently, invasive Mediterranean populations are only present in Eastern Spain and Italy (Lapini 1991; Ruiz-Olmo *et al.* 1997; Palazón and Ruiz-Olmo 1998; Spagnesi *et al.* 2002). Adapting to these Mediterranean environments implies adapting to the physical characteristics (temperature, humidity), type and structure of vegetation and highly strong seasonal patterns (strong autumn rainfalls and the subsequent flooding, and extremely dry and hot summers with dried rivers) (di Castri and Mooney 1973) in the region.

We tested potential morphological differences and possible factors that might affect it of an invasive population in Catalonia, Mediterranean Spain.

Material and methods

This study was conducted in the central-eastern part of Catalonia (Spain) (1º 53'N, 41º 49' E). We selected 20 km of the Llobregat River, 12 km of its tributary the

Gavarresa River, and their banks. The mink population in this area was the result of recently escaped (1980's) animals from two local fur farms. Specimens were obtained during four trapping sessions, summing up to a total of 6,216 trap-nights. Trapping was conducted in both rivers, between October and December 2003 (1,876 trap-nights), in January 2004 (588 trap-nights), and between October and December 2004 (1,876 trap-nights), and between October and December 2005 (1,876 trap-nights). Minks were live-trapped in single cage traps (15 x 15 x 60 cm) placed along the entire reach and located at a distance of 300-400 m from each other on both river banks and checked daily. After immobilization with 0.15 ml of ketamine (Imalgéne, Rhone Merieux, Lyon, France) and 0.03 ml of medetomidine (Domtor, Pfizer SA, Madrid, Spain), the captured animals were manipulated and released in the same capture area once fully recovered.

Trapped animals were marked with a transponder; in case of recapture we only used the measurements recorded from the first capture. The following morphological data were recorded: body weight (BW, precision 0.1 g); body length (BL), from the ventral edge of the nose to the anus; tail length (TL), from the anus to the tip of the tail, excluding fur; hindfoot length (HL), from the edge of the calcaneus to the tip of the third phalange; and ear length (EL), from the base of the tragus to the tip of the pinna. Lengths were taken on the left side of the animal in millimetres. Minks were classified as subadult (5-8 months old) or adult (>8 months old) based on teeth condition (Maran and Robinson, 1996).

A general lineal mixed model (GLMM) was used to analyse the fixed effect of year, sex, age and sex-age interaction on each morphological parameter. Statistical analyses were carried out with SAS statistical package version 9.0 (SAS Institute Inc., Cary, NC, USA). Sexual dimorphism was also evaluated using the index male measurement/female measurement (Table 3) (Moors 1980; Travaini and Delibes 1995).

Results

A total of 112 minks were captured, 79 new captures and 33 recaptures, with a total recapture rate of 1.8 minks per 100 trap-nights. Table 1 shows the results for the morphological analysis of the studied minks. For all morphological parameters considered, males (subadults and adults) were larger than females (subadults and adults). Table 2 shows the results for the GLMM, comparing the morphological parameters (dependent variables) with the year of capture and the biological parameters (independent variables). Sex had a significant effect on all the morphological parameters. Age had a significant effect on BW and BL. Year and sex-age interaction did not have significant effects on the morphology of the studied population. The mean index of sexual dimorphism was 1.20 (SD = 0.22, n = 6), ranging from 1.03 for TL to 1.63 for BW.

Discussion

The morphology of the American mink in the Catalonian Mediterranean area was slightly different from other populations. Adult minks in this population weighted more and were larger, in terms of full length, than American mink in populations from Ireland (1260 g, 605 mm for males; and 740 g, 511 mm for females), England (1100 g, 776 mm for males; and 620 g, 506 mm for females) and Estonia (1191 g for males, 633 g for females) (Farley 1980; Chanin 1983; Thom *et al.* 2004). Animals in populations from Canada (Banfield 1974) and from USA (Mitchell 1961) were also lighter than ours (1150 g for males; 600 g for females) and larger (580-700 mm for males, 460-575 mm for females) (Jackson 1961), unlike minks from Belarus, which were heavier and shorter (1310 g, 430 mm for males; and 780 g, 370 mm for females) (Sidorovich *et al.* 1999; Sidorovich 2001). In its native environment of North America, there are 15 currently accepted different subspecies (Linscombe *et al.* 1982), which were determined from morphological differences among geographic areas (Banfield 1974; Hall 1981; Nowak and Paradiso 1983). The high morphological variability of invasive American mink populations is likely due to a variety of different factors. Morphology of invasive populations is influenced by the subspecific origin of animals destined for fur farms since they differ morphologically. Introduced population will result in populations with morphological differences depending on the introduced subspecies in the area.

Three different mink subspecies, *M. v.vison*, *M. v. melampeplus* and *M. v. ingens*, were selected for introduction in fur farms all around Europe, Asia and South America (Dunstone, 1993). Also, escaped mink were required to adapt to new environments to ensure successful populations. These adaptations, likely based on unique environmental characteristics among regions, may have resulted in morphological changes. Distinctive morphological characteristics among regions may have also been influenced by the limited genetic pool of the ranched source animals, which was likely further restricted because only a small percentage of escaped animals were able to survive (Ruiz-Olmo 1987, Palazón and Ruiz-Olmo 1998, Palazón 2006).

Three factors affect American mink size and hence sexual dimorphism: prey availability, sexual selection and energetic waste (Sandell 1985). Based on our results, significant sexual dimorphism exists in the morphology of the invasive population studied. There were inter-sexual differences in BW, BL, TL, HL and EL. There was also a significant age effect on BW and BL (Table 2). This means adults were heavier and longer than subadults and the same occurred between males and females (adult males > subadult males > adult females > subadult females). However, there was no age-sex interaction effect for any parameter (Table 2), which might be due to the fact that subadult males already had larger morphological measurements than those of adult females. In fact SDI for adults and subadults were very similar and, sometimes even bigger for subadults. This result, and the fact that males gain relatively more mass than females do as they grow (Thom *et al.* 2004) suggests that subadult individuals were close to adult dimensions even though they were not yet sexually active, reaching sexual activity some months later in February (unpublished personal data). Therefore, since subadult minks were close to adult dimensions, sexual dimorphism was already apparent between subadults. The fact that dimorphism existed in subadult animals may suggest that males had a competitive advantage in feeding and/or hunting from an earlier age. Sexual selection has also been proposed as a cause for sexual dimorphism. It has been suggested that there is different selective pressures on members of each sex (Ralls 1977) and this may result to different morphological optima for males and females. For instance, there may be intrasexual selection regarding body size (Andersson 1994); larger males are reported to have more reproductive success and this is reinforced by female choice (Andersson 1994). Moreover, small females are favoured because they need less energy for daily maintenance and are probably more efficient at hunting small preys (Moors 1980). There is also an energetic basis. At least during the breeding season, males travel further than females (Yamaguchi and Macdonald 2003), male minks have greater growth rate post-weaning (Dunstone, 1993), and they may gain relatively more body weight during the final stages of growth (Thom *et al.* 2004).

The degree of sexual dimorphism obtained for BW and BL was lower than that obtained by Thom *et al.* (2004), Sidorovich *et al.* (1999, 2001), Banfield (1974) and Mitchell (1961). Mustelids in general (Moors 1980; Macdonald 2002), and minks in particular (Sealander 1943; Birks and Dunstone 1985), show sexual differences in the size of prey consumed and there is evidence of male mink preying on larger preys than females (Powell 1979; Birks and Dunstone 1985; Sealander 1943; Ireland 1990; Yamaguchi *et al.* 2003). This is known as the resource partitioning hypothesis and leads to sexual dimorphism (Brown and Lasiewski 1972; Dayan *et al.* 1989). In this study, only small preys were available (small mammals, crayfish, fish, Passeriformes and anuran), and both female and male mink fed mostly on crayfish, fish and small mammals (unpublished personal data). This apparent lack of trophic niche separation may explain the relatively smaller sexual dimorphism in this population. Further research, comparing diet and morphology of other Mediterranean mink's population, will be useful to further understand the morphological uniqueness among introduced American mink populations.

Acknowledgements

We wish to thank the "Universitat de Barcelona", the "Generalitat de Catalunya" and 02MNAT/8604 Life Project for funding this study. Y.M. is supported by a FPU Fellowship granted by the Spanish "Ministerio de Ciencia y Tecnología" (AP 2002-2653). We are also grateful to Joana Martelo, Albert Roura and the staff of the Servei de Protecció de Fauna (Generalitat de Catalunya). Also thanks to Vasco Batista for the English correction.

References

Andersson, M. 1994. *Sexual selection*. Princeton Univ. Press, Princenton.

Banfield, A. W. F. 1974. *The mammals of Canada*. Univ. Toronto Press, Toronto.

Birks, J. and Dunstone, N. 1985. Sex related differences in the diet of mink *Mustela vison*. -*Holarctic Ecoology* 8: 42-82.

Birks, J. and Dunstone, N. 1991. Mink *Mustela vison*. In: G. B. Corbertt and S. Harris (Eds): *The hand book of British mammals*, pp. 406-415. Blackwell.

Brown, J. H. and Lasiewski, R. C. 1972. Metabolism of weasels: the cost of being long and thin. -*Ecology* 53: 939-943.

Castri, di F. and Mooney, H. A. 1973. *Mediterranean type ecosystems: origin and structure*. Springer-Verlag, Berlin.

Chanin, P. R. F. 1983. Observations on two populations of feral mink *Mustela vison* in Devon. -*Mammalia* 4: 463-466.

Dayan, T. and Simberloff, D. 1994. Character displacement, sexual dimorphism, and morphological variation among British and Irish mustelids. -*Ecology* 75: 1063-1073.

Dayan, T., Simberloff, D., Tchernov, E. and Yom-Tov, Y. 1989. Inter- and intra-specific character displacement in mustelids. -*Ecology* 70: 1526-1539.

Dunstone, N. 1993. *The mink*. T and A D Poyserd Ltd, London.

Eagle, T. C. and Whitman, J. S. 1987. Mink. In: M. Novak, J. A. Baker, M. E. Obbard and B. Malloch (Eds): *Wild forbear management and conservation in North America*, pp. 615-624. Ontario Trappers Association, North Bay.

Erlinge, S. 1979. Adaptatve significance of sexual dimorphism in weasels. -*Oikos* **33**: 233-245.

Fairley, J. S. 1980. Observations on a collection of feral Irish Mink *Mustela vison* Schreber. -*Proceedings of the Royal Irish Academy Section B* **80**: 79-90.

Hall, E. R. 1981. *The Mammals of North America*, vol. II. John Wiley, New York.

Hedrick, A. V. and Temeles, E. J. 1989. The evolution of sexual size dimorphism in animals: hypothesis and tests. –*Trends in Ecology and Evoution* **4**: 136-138.

Ireland, M. C. 1990. *The behaviour and ecology of American mink Mustela vison (Schreber) in a coastal habitat*. PhD Thesis. Univ. Durham Press, Durham.

Jackson, H. H. T. 1961. *Mammals of Wisconsin*. Univ. Wisconsin Press, Madison.

Kondo, N., Saitoh, T. and Uraguchi, K. 1988. Age determination, growth and sexual dimorphism in the feral mink (*Mustela vison*) in Hokkaido. -*Journal of Mammalogy Society Japan* **13**: 63-75.

Kruska, D. C. T. and Sidorovich, V. E. 2003. Comparative allometric skull morphometrics in mink (*Mustela vison* Schreber, 1777) of Canadian and Belarus origin; taxonomic status. -*Mammalian Biology* **68**: 257-276.

Lapini, L. 1991. Il visone americano nel Fruili-Venezia Giulia. Fauna 2, 44-49.

Linn, I. and Birks, J. D. S. 1989. Mink (Mammalia; Carnivora; Mustelidae) correction of a widely quoted error. -*Mammal Review* **19**: 175-179.

Linscombe, G. Kinler, N. and Aulerich, R. J. 1982. Mink. In: J. A. Chapman and G. A. Feldhamer (Eds): *Wild mammals of North America: biology, management and economics*, pp. 629-643. Hopkins University Press, Baltimore, Md.

Macdonald, R. A. and Strachan, R. 1999. *The mink and the watervole: analyses for conservation*. Wildlife Conservation Research Unit and Enviroment Agency, Oxford.

Macdonald, D. W. 2002. Resource partitioning among British and Irish mustelids. -*Journal of Animal Ecology* **71**: 185-200.

Maran, T. and Robinson, P. 1996. *European mink Captive Breeding and Husbandry Protocol.* European mink Conservation and Breeding Committee, Tallin.

MacLennan, R. R. and Baley 1969. Seasonal changes in aggression, hunger and curiosity in ranch mink. -*Canadian Journal of Zoologogy* **47**: 1398-1404.

Mayr, E. 1963. *Animal Species and Evolution*. Belknap Press. Harvard University, Cambridge, MA.

Mitchell, J. L. 1961. Mink movements and populations on a Montana river. -*Journal of Wildlife Management* **25**: 48-54.

Moors, P. J. 1980. Sexual dimorphism in the body size of mustelids (Carnivora): the roles of food habits and breeding systems. -*Oikos* **34**: 147-158.

Nowak, R. M. and Paradiso, J. L. 1983. *Walker's Mammals of the World,* vol. II 4th. John Hopkins Univ. Press, Baltimore, London.

Palazón, S. 2006. Control del visón americano (*Mustela vison*) en Catalunya. Generalitat de Catalunya

Palazón, S. and Ruiz-Olmo, J. 1998. *El visón europeo (Mustela lutreola) y el visón americano (Mustela vison) en España*. ICONA, Madrid.

Powell, R. A. 1979. Ecological energetics and foraging strategies of the fisher (*Martes pennanti*). -*Journal of Animal Ecology* **48**: 195-212.

Powell, R. A. and Leonard, R. D. 1983. Sexual dimorphism and energy expenditure for reproduction in the female fisher *Martes pennanti*. -*Oikos* **40**: 166-174.

Ralls, K. 1977. Sexual dimorphism in mammals: avian models and unanswered questions. -American Naturalist **111**: 917-938.

Ruiz-Olmo. J. 1987. El visón americano, *Mustela vison* Schreber, 1777 (Mammalia, Mustelidae), en Cataluña, NE de la Península Ibérica. -D*oñana Acta Vertebrata* **14**: 142-145.

Ruiz-Olmo, J., Palazón, S., Bueno F., Bravo, C., Munilla, I. and Romero, R. 1997. Distribution, status and colonization of the American mink *Mustela vison* in Spain. -*Journal of Wildlife Research* **2**: 30-36.

Sandell, M. 1985. Ecological energetics and optimum size male and female stoats *Mustela erminea*: predictions and test. In: *Ecology and behaviour of the stoat*

Mustela erminea a theory on delayed implantation. PhD thesis, University of Lund, Sweden.

Sealander, J. A. 1943. Winter food habits of mink in southern Michigan. -*Journal of Wildlife Management* **7**: 411-417.

Sidorovich, V., Kruuk, H. and Macdonald, D. W. 1999. Body size, and interactions between European and American mink (*Mustela lutreola* and *M. vison*) in Eastern Europe. -*Journal of Zoology* **248**: 521-527.

Sidorovich, V. 2001. Study on decline in the European mink *Mustela lutreola* population in connection with the American mink *M. vison* expansion in Belarus: story of the study, review of the results and research priorities. -*Säugetierkundliche Informationen* **5**: 133-153

Smal, C. M. 1988. The American mink *Mustela vison* in Ireland. *Mammal Review* **18**: 201-208.

Spagnesi, C. M., Toso, S. and De Marinins, A. M. 2002. I Mammiferi d'Italia. Ministerio dell'Ambiente e della Tutela del Territorio e Instituto Nazionale per la Fauna Selvatica "Alessandro Ghihi", Roma.

Thom, M. D., Harrington, L. A. and Macdonald, D. W. 2004. Why are American mink sexually dimorphic? A role for niche separation. -*Oikos* **105**: 525-535.

Travaini, A. and Delibes, M. 1995. Weight and external measurements of red foxes (*Vulpes vulpes*) from SW Spain. –*Zeitschrift für Säugetierkunde* **60**: 121-123.

Vidal-Figueroa, T. and Delibes, M. 1987. Primeros datos sobre el visón americano (*Mustela vison*) en el Suroeste de Galicia y Noroeste de Portugal. -*Ecología* **1**: 145-152.

Yamaguchi, N. and Macdonald, D. W. 2003. The burden of co-occupancy: intraspecific resource competition and spacing pattern in American mink, *Mustela vison*. -*Journal of Mammalogy* **84**: 1341-1355.

Yamaguchi, N., Rushton, S. and Macdonald, D. W. 2003. Habitat preferences of feral mink in the Upper Thames. -*Journal of Mammalogy* **84**: 1356-1373.

Table 1 Mean values, standard deviation (SD) and range for body weight (BW), body length (BL), tail length (TL), hindfoot length (HL) and ear length (EL). Mass is in g, and lengths are in mm, n = number of measured minks.

	Subadult		Adult	
Variable	Male n = 17	Female n = 16	Male n = 36	Female n = 10
BW				
Mean	965.18	593.87	1133.06	767.60
Range	767-1233	460-743	830-1554	526-1474
SD	133.68	88.55	163.00	290.30
BL				
Mean	415.29	351.69	435.19	386.70
Range	390-440	250-392	370-500	350-460
SD	13.58	33.99	28.26	36.67
TL				
Mean	206.65	180.88	210.83	181.60
Range	162-230	150-210	120-241	150-205
SD	22.23	13.70	21.77	15.82
HL				
Mean	65.76	59.13	69.36	63.10
Range	50-74	45-75	45-91	57-80
SD	15.47	7.99	10.27	7.02
EL				
Mean	22.12	19.88	23.92	20.90
Range	19-28	14-28	16-30	19-30
SD	2.15	3.67	3.28	3.25

Table 2 GLMM results for the analyses of morphological parameters: BW, BL, TL, HL and EL. No factors were introduced as random effects in the models. d.f.: degrees of freedom.

Model-fixed effect	F	d.f.	P
BW			
Year	1.60	2	0.217
Sex	23.41	1	<0.0001
Age	9.54	1	0.004
Age-sex interaction	3.32	1	0.078
BL			
Year	2.48	2	0.099
Sex	33.31	1	<0.0001
Age	9.72	1	0.041
Age-sex interaction	2.61	1	0.116
TL			
Year	1.02	2	0.365
Sex	27.54	1	<0.001
Age	0.56	1	0.457
Age-sex interaction	0.11	1	0.745
HL			
Year	1.75	2	0.181
Sex	11.02	1	0.001
Age	2.69	1	0.105
Age-sex interaction	0.25	1	0.618
EL			
Year	1.43	2	0.260
Sex	16.44	1	<0.0001
Age	1.14	1	0.288
Age-sex interaction	0.05	1	0.818

Table 3 Sexual dimorphism index (SDI) for: BW, BL, TL, HL and EL. SD = standard deviation.

Variable	Subadult	Adult	Total
BW	1.62	1.50	1.63
BL	1.18	1.13	1.17
TL	1.14	1.16	1.03
HL	1.11	1.09	1.12
EL	1.11	1.14	1.15
Mean	1.23	1.20	1.21
SD	0.22	0.16	0.22

RESUMEN

La introducción de una especie en zonas fuera de su área natural de distribución implica una aclimatación y, a largo plazo, una adaptación a los distintos ecosistemas (Sidorovich *et al.*, 1999; Sidorovich, 2001). En el caso del visón americano diversos autores han puesto de manifiesto diferencias morfológicas en función de las diferentes zonas en las que la especie ha sido introducida (Dunstone, 1993; Dayan y Simberloff, 1994; Kondo *et al.*, 1988; Birks y Dunstone, 1991; Kruska y Sidorovich, 2003). En el presente trabajo se analizan los resultados del estudio morfológico de una población asilvestrada de visón americano en la Cataluña central. Dicho trabajo se ha realizado con el objetivo de determinar si se manifiestan las diferencias morfológicas antes comentadas.

El estudio se realizó a lo largo de 20 km del río Llobregat y a lo largo de 12 km de su afluente la riera Gavarresa. Para la captura de los ejemplares, se colocaron un total de 6216 trampas noche en cuatro sesiones de muestreo: octubre –diciembre de 2003 (1876 trampas noche), enero 2004 (588 trampas noche), octubre –diciembre de 2004 y 2005 (1876 trampas noche en cada sesión). Los ejemplares capturados fueron anestesiados, manipulados y liberados una vez que se recuperaron totalmente de los efectos de la anestesia. En total se capturaron 79 individuos; los datos correspondientes a los individuos recapturados han sido considerados una sola vez. Se han analizado los siguientes parámetros morfológicos: peso (BW), longitud (BL), longitud de la cola (TL), longitud del pie posterior (HL) y longitud de la oreja (EL).

Para el análisis de los datos se ha utilizado un modelo lineal general mixto (GLMM) para determinar el efecto del año de muestreo, la edad, el sexo y la interacción sexo-edad. El grado de dimorfismo sexual se ha evaluado utilizando el índice de

dimorfismo sexual (medidas de los machos/medidas de las hembras) (Moors, 1980; Travaini y Delibes, 1995).

Los resultados obtenidos se representan en la tabla 1. Los resultados indican que el sexo está significativamente correlacionado con BW, BL, HL y EL, y la edad con BW y BL. Las demás variables no presentan una correlación significativa (Tabla 2). El índice medio de dimorfismo sexual es de 1,20 (SD = 0,22, n = 6) (Tabla 3).

En base a los resultados obtenidos cabe considerar que la morfología del visón americano, en la población estudiada, difiere ligeramente de la que presentan ejemplares pertenecientes a otras poblaciones (Mitchell, 1961; Banfield, 1974; Farley, 1980; Linscombe *et al.*, 1982; Chanin, 1983; Sidorovich *et al.*, 1999; Thom *et al.*, 2004). El dimorfismo sexual ya se observa entre los subadultos estudiados, lo cual indica una cierta ventaja competitiva temprana para los machos. No obstante, cabe decir que, si bien se detecta dimorfismo sexual entre los machos y las hembras de la población estudiada tanto en subadultos como adultos, éste resulta menor al esperado teniendo en cuenta los observados en las poblaciones estudiadas por Mitchell (1961) en su área original de Estados Unidos, y en poblaciones introducidas como las estudiadas por Sidorovich *et al.* (1999) en el este de Europa, y Thom *et al.* (2004) en Reino Unido.

Según estos datos, parece que, desde su introducción en la población de visón americano de la Cataluña central hace 20 años, ha tenido lugar una adaptación paulatina al ambiente de tipo mediterráneo, reduciéndose las diferencias morfológicas entre ambos sexos. Se postula que la causa más plausible para esta disminución del dimorfismo es el pequeño tamaño de las presas del visón en la zona de estudio (Melero *et al.*, enviado). Dado que se considera que una de las posibles causas que determinan el dimorfismo en la especie es la separación del nicho trófico entre los individuos de diferente sexo, en el presente caso, la uniformidad en el tipo de recursos que explotan ambos sexos (datos personales) puede provocar la aproximación de las tallas.

Feeding habits of three sympatric mammals in NE Spain: the American mink, the spotted genet, and the Eurasian otter*

Yolanda MELERO, Santiago PALAZÓN[1,2], Laura BONESI[3], and Joaquim GOSÀLBEZ[1].

Abstract

Diet composition, niche measures, and prey consumption of three sympatric species of carnivores, one introduced, the American mink, and two native, the spotted genet and the Eurasian otter, were studied in a Spanish Mediterranean area. The study was based on the analysis of prey remains in the faeces of the predators. Faeces of mink (n = 444), genet (n = 310), and otter (n = 108) were collected all year round for four years along the Llobregat (21 km) and Gavarresa rivers (12 km). Simultaneously and in the same area prey species density and weight were estimated by means of trapping. Frequency of occurrence, relative frequency of occurrence and biomass consumption of prey species were calculated for each of the three predators. Mink and genet fed primarily on American crayfish, thought fishes for the genet, and birds and fishes for mink, were as important as crayfish when considering biomass consumption. Meanwhile, otter fed almost exclusively on fish. Seasonal variations in the frequency of prey categories consumed (mammals, birds, fish, invertebrates and American crayfish) were observed, especially in mink and genet. Niche breadth showed marked seasonal differences for genet and otter, while it remained constant across seasons for mink. Niche overlap was higher between mink and genet than between any of them and the otter. Finally, mink and genet showed a tendency to take mammalian species according to their availability. The results indicate that there is potential for these three species to compete for food and highlight that all three species rely heavily on aquatic resources, but while mink and genet choose the American crayfish as their elected aquatic prey, the otter relied very heavily on fish.

Department of Animal Biology (Vertebrates), University of Barcelona, Av. Diagonal, 645, 08028, Barcelona, Spain, e-mail: melero@ub.edu (YM), jgosalbez@ub.edu (JG); Department of Environment and Housing, Generalitat de Catalunya, Doctor Roux, 80, 08017, Barcelona, Spain, santiago.palazon@gencat.net (SP); Department of Biology, University of Trieste, Via Weiss 2, 34127 Trieste, Italy lbonesi@units.it (LB).

Keywords: diet, sympatry, mink, genet, otter, competition.

Running header: Feeding habits of sympatric mink, otter and genet

---

* Acta Thereologica, submitted.

Introduction

The non-native American mink, *Mustela vison*, inhabits several European rivers having established feral populations following accidental or deliberated escapes from mink farms throughout Europe (Bonesi and Palazón, 2007). While the American mink continues its spread, it has been shown that the presence of other predators, in particular the Eurasian otter, *Lutra lutra*, can slow down its invasion front (Ruiz-Olmo, *et al.*, 1997) and can negatively affect its populations (Bonesi and Macdonald, 2004b). Otter are about seven times larger than mink and better at hunting aquatic prey (Dunstone, 1979); therefore they are expected to be the stronger competitor. To counter-act the greater size and strength of the otter, the mink is gifted with a great adaptability in terms of its diet requirements. Indeed, while the otter is specialised on a diet based mainly on fish and other aquatic prey (e.g. McDonald, 2002; Adrian and Delibes, 1987; Lanszki and Körmendi, 1996; Sidorovich, 1997; Pikulik, Sidorovich, Jedrzejewska and Jedrzejewski, 2001), mink is more of a generalist and opportunist feeding both on aquatic and terrestrial prey in varying proportions (e.g. McDonald, 2002; Hammershøj, Thomsen and Madsen, 2004). Such flexibility allows mink to adapt its diet to the local availability of food resources (Jedrzeijewska, *et al.*, 2001) and, when necessary, to adapt its diet to the presence of competitors that may preclude access to specific resources. In particular, a number of studies have shown that in the presence of the Eurasian otter, mink tends to change its diet toward one based more on terrestrial prey to avoid relying on aquatic food resources that are more intensely exploited by the otter (Clode and Macdonald, 1995; Bueno, 1996; Bonesi, Chanin and Macdonald, 2004). Mink are also known to interact with other European mustelids, namely the European mink (*Mustela lutreola*) and the Eurasian polecat (*Mustela putorius*), and it has been shown that this alien species can exert a negative effect on the population density of both natives (Maran *et al.*, 1998; Sidorovich and Macdonald, 2001) probably mostly by means of direct aggression (Maran *et al.*, 1998; Sidorovich, *et al.*, 2000). The trophic niche of the American mink, the European mink, the Eurasian polecat and the Eurasian otter can considerably overlap. For example, studies in Belarus and Poland recorded niche overlap values for these four species using Pianka´s adaptation for Levin's index that ranged from a minimum of 40% to a maximum of 86% (Sidorovich, 1992; Jedrzeijewska, *et al.*, 2001). While studies on diet alone cannot resolve whether there is or not competition between two or more species, the level of resource overlap between species can be a useful indicator of whether the conditions for interspecific competition are present, as the joint exploitation of resources is a prerequisite for competition to occur (Wiens, 1989).

In this study, we examine the diets of the American mink, the spotted genet, *Genetta genetta,* and the Eurasian otter in an area of north-east Spain to determine their trophic niche overlap and therefore the potential for these species to compete.

We also examine the trophic niche breath of all three species, seasonal differences in the composition of their diets, and opportunism by mink and genet, namely whether mammalian prey are taken according to their availability.

In Spain, the first mink farms were set up at the end of the 1950s and mink were first recorded in the wild in the 1978 (Delibes and Amores, 1978). Currently mink have established six populations throughout the country (Ruiz-Olmo *et al.*, 1997). At the same time while mink were establishing their feral populations, Eurasian otter were suffering a decline starting in the 1970s because of deforestation, river pollution and human pressure (Delibes, 1990). Since the early 1990s, habitat improvements and re-introduction programs have fostered the otter's recovery (Ruiz-Olmo and Delibes, 1998a) and otter populations are now colonising areas inhabited by the American mink. In Spain, these two species of Mustelids share the riparian habitat with the spotted genet (*Genetta genetta)*, a carnivore weighting about 2 kg of the family of the Viverridae that is widely distributed throughout the country (Mitchell-Jones, *et al.*, 1999). Its size and its frequentation of riparian habitats make the spotted genet a potential competitor of the American mink (Ruiz-Olmo and Aguilar, 1995).

While several studies have compared the diet of the American mink and the Eurasian otter (e.g. Erlinge, 1972; Jenkins and Harper, 1980; Chanin, 1981; Clode and Macdonald, 1995; Bueno, 1996; Jedrzejewska *et al.*, 2001; Bonesi *et al.*, 2004), and some studies have compared the diet of the European mink and the spotted genet (Palazón, 1998; Palazón, Ruiz-Olmo and Gosàlbez, in press), to our knowledge this is the first study to compare the diet of the American mink and the spotted genet in conditions of sympatry.

Study area

The study area comprises 21 km of the Llobregat River and 12 km of its tributary, the Gavarresa River (Fig. 1) which are located in north-east Spain (1º 53'N, 41º 49' E). The rivers host Cyprinids, Salmonids, and the introduced American crayfish (*Procambarus clarkii*). The riparian forest of both rivers is typically Mediterranean dominated by *Arundo donax*, *Typha latifolia*, *Phragmites communis*, *Juncus* spp., *Rubus ulmifolius*, *Populus alba* and *Salix* spp. Small rodents such as the house mouse *Mus musculus* and the wood mouse *Apodemus sylvaticus*, inhabit the riparian forest. In the past, both rivers were polluted by nearby industry estates, cities and villages as well as agriculture fields, but in the last 15 years pollution levels have decreased thanks to the openings of several water-treatment plants (Ruiz-Olmo and Delibes, 1998b). Mink has been present in the area since 1982 introduced from the two local mink farms because of several small unintentional releases and a large escape following a fire (Palazón and Ruiz-Olmo, 1998). The otter went extinct in this area in the 1970s but re-colonised the rivers Llobregat and Gavarresa since the year 2000 as a result of a reintroduction project that took place between 1995 and 1999 in l'Empordà (Girona), just north of the study area (Saavedra, 2003) and possibly also as a result of natural spread from the western otter's populations located in the river Segre. Spotted genet also inhabits the area (Ruiz-Olmo and Aguilar, 1995).

Materials and methods

Collection and analysis of faeces

Mink, otter, and genet faeces were collected between 2002 and 2005 in spring-summer (April 1-September 30) and in autumn-winter (October 1-March 30). A total of 444 mink scats, 108 otter spraints, and 310 genet faeces were collected. Faeces were attributed to each species based on their appearance and smell. Mink scats are usually compact and are about 0.9 cm in diameter and present a strong characteristic foetid odour easy to recognise. Otter spraints vary in shape but they have a characteristic sweet-musky odour. Genet faeces found in the riparian habitat can be similar to mink scats, but they are usually larger than those of mink (about 1.3 cm in diameter) and do not have the characteristic smell of mink scats (see Livet and Roeder, 1987; Dunstone, 1993). When faeces were not fresh enough to allow distinction between the three species they were removed from the area and not considered in the analyses. After collection, samples were soaked in water and washed through a sieve (1 mm mesh). Whenever possible, prey remains were identified down to the species level and attributed to a species or group by comparison with our own reference collection, especially in the case of bird's feathers, or by using published identification keys. In particular, the key by Gosàlbez (1987) was used for mammals' teeth; the key by Teerink (1991) was used for mammals' hairs; the key by Miranda and Escala (2002) was used for fishes' scales and jaw apparatus; and the key by Rage (1974) for reptiles. Invertebrates were classified to the Subphylum level (Cheliceromorphos and Myriapoda), to the Class level (Gasteropoda), or to the Order level for insects as exoskeletons were easyly recognisable. Amongst Invertebrates, only the American crayfish *Procambarus clarkii* was easily identified to the species level, as there were no other species of crayfish in the area. Vegetation was not considered as a food item since it was probably ingested incidentally.

Prey species

Prey species were trapped in the study area for two reasons: (i) to estimate their relative abundance; (ii) to measure their weight to calculate the index of biomass consumption (see below). For small mammals, four trapping sessions of 200 trap-nights per session were conducted during 2003. Two sessions were set during spring-summer and another two in autumn-winter. Animals were live-trapped in Sherman traps located on the river-banks and checked every day. Captured animals were identified, measured, weighted and released. Crayfish were also trapped in both seasons during 2003 (one trapping session per season) using a small net. They were then measured, weighted and released. We did not trap fish, birds and Invertebrates. To estimate weight of fish, we measured the pharyngeal teeth and cervical and caudal vertebrae of remains in the predators' faeces, and then transformed these values into weight by using the regression functions calculated by Ruiz-Olmo (1995) and Miranda and Escala (2002). The mean weights of birds and Invertebrates were derived from those estimated by Delibes (1974).

Diet composition and temporal variations

Composition of the three species' diets was expressed as frequency of occurrence (FO), relative frequency of occurrence (RFO), and percentage of biomass consumption (B) of prey items (Conroy *et al.* 1993). FO was calculated by dividing the number of scats where each prey item was present by the total number of scats. RFO was calculated by dividing the total number of occurrences of each prey item by the total number of items found. Each species was considered an item whenever possible, when identification to the species level was not possible the lower identified taxa was considered as item. To calculate B, the total number of occurrences of each prey item was multiplied by the mean weight of the prey (see above) (Delibes, 1974; Gosàlbez, 1987) and then divided by the total estimated B, to give the relative masses of the prey consumed. Besides considering the consumption of single species, we also calculated RFO and B for the following prey categories: mammals, birds, fishes, invertebrates, reptiles and American crayfish. The last one was included as a category separated from invertebrates due to its high representation in the diet of mink and genet.

To ascertain that it was possible to pool together data from different years, annual variation of RFO and B consumption for the main prey categories (mammals, birds, fish, and American crayfish) was tested using a chi-square. The effect of season on diet composition (RFO and B), where by season we mean the two periods of 'spring-summer' and 'autumn-winter', was also tested using a chi-square test.

Selection of mammal species

Whether mammalian prey species were taken according to their availability was studied for the American mink and the spotted genet by regression analysis where the RFO of each prey species in the diet was studied in relation to the number of individuals that were trapped in the study area.

Niche measures

Niche breadth and niche overlap were calculated based on prey items using Hurlbert's standardisation of Levin's formula (Hurlbert, 1978; Levin 1968) for niche breadth ($B = [(1/ \sum P_i^2) - 1] / [n - 1]$; where B = niche breadth, P = resource, and n = total number of resource) and Pianka's adaptation of Levin's formula for niche overlap ($\alpha_{1,2} = \sum P_{1i} * P_{2i} / \sum \sqrt{} P_{1i}^2 * P_{2i}^2$; where α = overlap between species 1 and species 2, and P = resource) (Pianka, 1973). Both indices range between 0 and 1.

Results

Prey species

The number of specimens of mammals and crayfish and their mean weight together with the mean weight estimated for fish from their remains in the faeces are shown in table 1. Three species of mammals and one species of crayfish were captured. The most abundant mammal in the area was the house mouse. Amongst mammals, mean weights of the wood mouse and the house mouse differed significantly, or almost significantly, at the 0.05 level between seasons ($U = 209.5$, $df = 1$, $p < 0.001$; $U = 581$, $df = 1$, $p = 0.056$); meanwhile the greater white-toothed shrew *Crocidura russula* didn't show statistically significant seasonal differences in its weight ($U = 144$, $df = 1$, $p = 0.11$). Fish and crayfish did not show significant seasonal differences in their weight (U from 1 to 50, df = 1, p from 0.27 to 1) except in the case of the Iberian nase, *Chondrostoma meigii* (U = 345.5, df = 1, p = 0.02) (Table 1).

Diet composition

There were no significant differences in the RFO and estimated B of the main prey categories (mammals, birds, fish, invertebrates and American crayfish) among the four years of study for the American mink, the spotted genet or the Eurasian otter (for all cases $\chi^2 < 16.03$, df = 9, $p > 0.10$). Therefore, data from all years were pooled together for the analyses.

In general, for mink and genet the relative abundance of prey categories in the diet calculated using the RFO was substantially different from that calculated using B (Fig. 2 and 3), while there were no substantial differences in the results given by the two indices for the otter (Fig. 2 and 3). When using the RFO (Fig. 2) the American crayfish resulted by far the main prey of both mink and genet, while when considering also prey size in the index of B, other prey categories such as fish, mammals and birds were equally important (Fig. 3). The otter's diet was very different from that of the mink and the genet, and characterised by a heavy reliance on fish whichever index was used.

When looking more in detail at the single prey species, it emerged that mink and genet in spite of similar preferences in terms of prey categories, ate different species. For example, when B of mammals was considered, the most eaten prey by the genet was *Rattus* spp, especially in autumn-winter, while rats were not important in the diet of mink (Tables 2 and 3). Both predators ate water voles, *Arvicola sapidus*, especially in spring-summer. It is interesting to note that in autumn-winter mallards, which were equally important for mink and genet in spring-summer, completely disappeared from the diet of the genet (Table 3), while they became an important prey species in the diet of mink (Table 2). Barbels were the most important fish species in terms of B for all three predators followed by salmon. But, while mink and genet consumed salmon in spring-summer and not in autumn-winter, the contrary was true for otter (Tables 2, 3 and 4). However, the proportion of unidentified fish in autumn-winter for the otter was rather high and this may alter the relative frequency of salmon found (Table 4).

Seasonal variation of diets

Mink and genet showed statistically significant seasonal differences in the B of the main prey categories (Mink: $\chi^2 = 40.83$, df = 3, $p < 0.001$; genet: $\chi^2 = 61.44$, df = 3, $p < 0.001$). The diet of genet showed seasonal differences also when the RFO of prey categories was used as an index ($\chi^2 = 13.82$, df = 3, $p < 0.001$) while mink did not ($\chi^2 = 5.19$, df = 3, $p = 0.13$). It was not possible to apply the chi-square test to verify statistically significant seasonal differences when considering all prey categories for the otter because all these, apart from fish (RFO and B) and crayfish (RFO), had a frequency lower than five. When considering only RFO for fish and crayfish otter did present any statistically significant seasonal differences in their diet ($\chi^2 = 4.88$, df = 1, p = 0.03).

Selection of mammal species

There was a relationship between the RFO of mammalian prey species in the diet of mink and genet and the abundance of these prey species as estimated by the number of captures (Fig. 4a and 4b). However, this relationship was significant at the level of 0.05 for mink (F = 12.2, p = 0.025; Fig. 4a) but not for genet (F = 3.52, p = 0.13; Fig. 4b).

Niche measures

The values of niche breadth for the three species were relatively comparable in spring-summer, while in autumn-winter the values differed markedly, with the otter reducing, the genet increasing and the mink maintaining the same value of niche breadth as in spring-summer (Table 5). Niche overlap was higher between the mink and the genet than between any of the two smaller predators and the otter (Table 5). There was no great seasonal variation in the indixes of niche overlap

(Table 5). Regarding trophic niche breadth, the value for mink observed in this study is comprised within those observed for the species that range between 0.09 and 0.31 and that of the otter within those observed for the species that range between 0.01 and 0.15 (McDonald, 2002).

Discussion

The results have shown that in this specific case study the American mink and the spotted genet tended to have similar diets partitioned between aquatic and terrestrial prey, while the otter fed almost exclusively on aquatic prey. Moreover, when feeding on aquatic prey, the kind of species selected by the mink and the genet were different from those of the otter. While the former two species concentrated on the American crayfish the latter relied very heavily on fish.

As far as the otter diet is concerned, our study confirms the observations of Ruiz-Olmo (2001) for this species in Mediterranean areas by showing that the barbel and the Iberian nase are the most important fish prey consumed. The levels of crayfish consumption by otter that we found (RFO 8-18) are comparable to those found in other areas of the Palearctic region (RFO 16±3SE) where crayfish are also particularly abundant (Jedrzeijewska, *et al.*, 2001) as in our area (see below), like for example in Ireland (Kyne, Smal and Fairley, 1989). However, consumption of fishes in the Paleartic region by otter tended to decrease between spring-summer (RFO 51) and autumn-winter (RFO 40) (Jedrzeijewska, et al., 2001), meanwhile in our area between these two seasons consumption of fishes increased from 91 to 98 RFO.

As far as the spotted genet is concerned, while the diet of this species at northern latitudes in Eurosiberian locations tends to be based mostly on small mammals (Lodé, Lechat and Le Jacques, 1991; Le Jacques and Lodé, 1994), in Mediterranean areas it has been shown to be more diverse including arthropods, amphibians and reptiles (Virgós, Llorente and Cortés, 1999). Our study confirms this observation as we found the diet of the genet to comprise a diversity of prey categories such as mammals, birds, fish, reptiles and invertebrates and to be actually the most diverse of all the three studied carnivores in the period autumn-winter (Table 3). The particularly high levels of predation of aquatic prey, crayfish and fish, by the genet in the study area was similar to that found in other studies in Mediterranean areas (Ruiz-Olmo and López-martín, 1993; Alcover, 1984). In our study area this high consumption of crayfish and fish by the genet may be due to the existence of several low depth pools along the river that may have facilitated hunting aquatic prey by a species that is not particularly adapted to hunting in the water.

The diet of the American mink has been well studied in some northern countries like, for example, the UK (reviewed by MacDonald 2002) while fewer studies have been conducted in Mediterranean areas (e.g. Bueno, 1994, 1999; Palazón and Ruiz-Olmo, 1998, Díez and Lizana, 1999). The American mink is an opportunist and its diet in Mediterranean areas showed some variability possibly depending on the kind of species available in the different areas. For example, fish, crayfish and mammals were the main prey sources in the rivers Moros and Voltoya of Central Spain (Bueno, 1994, 1999; Díez and Lizana, 1999).

The American crayfish was the most consumed prey by both mink and genet in this study. Crayfish has the disadvantage of being a relatively small prey, of having a low digestibility coefficient, and of requiring a long handling time (Ruiz-Olmo, Jiménez and Margalida, 1998), making it a scarce source of energy. Nevertheless, in our study area crayfishes can be found in abundance in numerous patches, with biomass densities that even exceed those of fish (data from the Department of Environment and Housing, Catalonian Government). Moreover, crayfish represents a constant food source available all year round which is relatively easy to catch as it stays close to the shoreline, usually on the roots of the helophytic vegetation. Under these conditions, the net benefit seems to be sufficient for mink and genet to elect crayfish as their main food source. The fact that crayfish provides enough energy for mink in the area is confirmed by two observations: (i) that the body conditions of individual mink are relatively good (Melero, Palazón and Gosàlbez., in press); and (ii) that mink are found at very high densities of about 1.16 mink/km (Melero pers. obs).

The generalist behaviour of mink and genet, also shown by the relatively high levels of niche breadth observed, makes it possible for them to vary their diet seasonally depending on the abundance of species, as also observed by other authors (Ruiz-Olmo and López-Martín, 1993; Sidorovich, 1992, 2000; Jedrzeijwska, *et al.*, 2001); Virgós *et al.*, 1999). We also observed that genets and mink show opportunistic behaviour with regard to mammalian prey, in the sense that they seemed to take mammalian species according to their availability as estimated by trapping. However, the relationship between the abundance of mammalian species and the presence of these in the diet was stronger for mink than for genets. It is possible that this difference was due to the fact that mammals were trapped along the river, where mink are most likely to hunt, while the prevalence of mammals in the diet of the genet may be more influenced by the abundance of mammals species that live inland further away from the water, which may be different from that along the river.

An interesting question that springs from the comparison of diets of potential competitors concerns how much of the observed diet composition reflects the availability of prey in the area and the morpho-physiological constraints of the species, and how much is due instead to competition between these different carnivores. By comparing our results with those of other studies (see above) and, for genets and mink, with the abundance of mammalian prey species in the area there does not seem to be any unexpected observation in the consumption of prey items by these three species, therefore it is possible that levels of competition are relatively low. Otters have only recently re-colonised the area and are found at low densities, indeed the number of otter spraints found in this study was relatively low compared to that of mink scats while it has been observed that in areas where both otter and mink are abundant more otter spraints than mink scats tend to be found (Bonesi and Macdonald, 2004a). Mink on the other hand, were particularly abundant in the area reaching densities of 1.16 mink/km (Melero pers.obs.), which are comparable to those of mink in coastal habitats in the UK (2.0 mink/km) where they are known to be particularly abundant (Dunstone and Birks, 1985). The scarcity of otter and the abundance of mink in the study area may determine low levels of competition between these two mustelids that are known to compete elsewhere (e.g. Ruiz-Olmo, et al., 1997; Bonesi and Macdonald, 2004b). Regarding the mink and the genet, we found that niche overlap between these two species was low (37% in spring-summer and 33% in autumn-winter), although higher than between the mink and the otter. On the other hand, genet samples were collected only in the riparian habitat, while it is known that genets prey also away from rivers as this species is not as aquatic as otters and mink and its territories are bi-dimensional and not linear and restricted to a narrow riparian strip like those of the two mustelids (Livet and Roeder, 1987). For this reason, genet faeces found in the riparian habitat may also contain prey that may have been captured in the wooden areas away from the river which may lead to an under-estimation of the level of dietary overlap between genets and mink.

Taken all together the above observations suggest that otters and genets are not likely to be, at the moment, important competitors for the mink population in the study area and in general in the rest of Catalonia where conditions are likely to be similar. The good status of the mink population and the fact that competitors are not likely to have a significant impact raises an important conservation issue as it reinforces the necessity for artificial control and proactive management of the invasive American mink in Catalonia. This is especially important in view of the highly likely danger that the actual Catalonian population reaches the Ebro river basin and from there enters into contact with the eastern side of the European mink population, which is one of the few left in the Iberian Peninsula and in Europe.

Acknowledegments

We thank “Universitat de Barcelona”, “Generalitat de Catalunya” and 02MNAT/8604 Life Project for funding this study. Y.M. is supported by a FPU Fellowship granted by the Spanish “Ministerio de Ciencia y Tecnología” (AP 2002-2653). We are grateful to the “Dipartimento di Biologia, Universita’ di Trieste” for offering a lab to analyse the samples. We also thank Albert Roura and Joana Martelo for their collaboration in taking samples in the field. Laura Bonesi was sponsored by the program ‘Incentivazione alla mobilità di studiosi stranieri e italiani residenti all’estero’.

References

Adrian, M.I. and Delibes, M. 1987. Food habits of the otter (*Lutra lutra*) in two habitats of the Doñana National Park, SW Spain. Journal of Zoology 212, 399-406.

Alcover, J.A. 1984. Über die Nahrung der Ginterkatze *Genetta genetta* auf den Inseln Mallorca, Ibiza und Cabrera. Säugetierkundliche Mitteilungen 31: 189–195.

Bonesi, L. and Macdonald, D. W. 2004a. Evaluation of sign surveys as a way to estimate the relative abundance of American mink (*Mustela vison*). Journal of Zoology 262: 65-72.

Bonesi, L. and Macdonald, D. W. 2004b. Impact of released Eurasian otter on a population of American mink: a test using an experimental approach. Oikos 106: 9-18.

Bonesi, L., Chanin, P. and Macdonald, D.W. 2004. Competition between Eurasian otter *Lutra lutra* and American mink *Mustela vison* probed by niche shift. Oikos 106: 19-26.

Bueno, F. 1994. Alimentación del visón americano (*Mustela vison* Schreber) en el río Voltoya (Ávila, cuenca del Duero). Doñana Acta Vertebrata 21: 5-13.

Bueno, F. 1996. Competition between American mink *Mustela vison* and otter *Lutra lutra* during winter. Acta Theriologica 41: 149-154.

Chanin, P.R.F. 1981. Diet of the otter (*Lutra lutra*) in relation to feral mink (*Mustela vison*) in two areas in Southwest England. Acta Theriologica 26: 83-95.

Clode, D. and Macdonald, D.W. 1995. Evidence for food competition between mink and otter on Scottish islands. Journal of Zoology 237: 435-444.

Conroy, J.W.H., Watt, J.P., Webb, J.B. and Jones, A. 1993. A guide to the identification of prey remains in otter spraints. London: The Mammal Society.

Delibes, M. 1974. Sobre alimentación y biología de la Gineta (*Genetta genetta* L.) en España. Doñana Acta Vertebrata 1: 143-199.

Delibes, M. 1990. La nutria (*Lutra lutra*) en España. Serie Técnica. ICONA. Madrid.

Delibes, M. and Amores, F. 1978. On the distribution and status of the Spanish carnivores. In II International Theriological Congress, Brno (CSSR).

Díez, D. and Lizana, M. 1999. Distribución, dieta y competencia trófica del visón americano (*Mustela vison*) y la nutria (*Lutra lutra*) en un río del Sistema Central, río Moros, Segovia. Resúmenes IV Jornadas SECEM, Segovia, 34.

Dunstone, N. 1979. Swimming and diving behaviour of the mink (*Mustela vison* Schreber). Carnivore 2: 56-61.

Dunstone, N. 1993. The mink. London: T and A D Poyserd Ltd.

Dunstone, N. and Birks, J. D. S. 1985. The comparative ecology of coastal, riverine and lacustine mink *Mustela vison* in Britain. Zeitschrift fur Angewardte Zoologie 72: 59-70.

Dunstone, N. and Birks, J. D. S. (1987). The feeding ecology of mink (*Mustela vison*) in coastal habitat. Journal of Zoology 212: 69-83.

Erlinge, S. 1972. Interspecific relationships between otter (*Lutra lutra*) and mink (*Mustela vison* Schreber) in Sweden. Oikos 23: 327-334.

Gosàlbez, J. 1987. Insectívors i Rossegadors de Catalunya. Metodologia d'estudi i Catàleg faunístic. Barcelona: Ketres.

Green, J., Green, R. and Liles, G. 1986. Interspecific uses of resting sites by mink Mustela vison and otter Lutra lutra. London: The Vincent Wildlife Trust.

Hammershøj, M., Thomsen, E. A. and Madsen, A. B. 2004. Diet of free-ranging American mink and European polecat in Denmark. Acta Theriologica 49: 337-347.

Hurlbert, S.H. 1978. The measurement of niche overlap and some relatives. *Ecology* 59: 67-77.

Jedrzejewska, B., Sidorovich, V. E., Pikulik, M. M. and Jedrzejewski, W. 2001. Feeding habits of the otter and the American mink in Bialowieza Primeval Forest (Poland) compared to other Eurasian populations. Ecography 24: 165-180.

Jenkins, D. and Harper, R. J. 1980 Ecology of otter in northern Scotland. II, analyses of otter (*Lutra lutra*) and mink (*Mustela vison*) faeces from Deeside NE Scotland in 1977-78. Journal of Animal Ecology 49: 737-754.

Keddy, P.A. 2001. Competition. London: Kluwer Academic Publisher.

Kyne, M. J., Smal, C. M. and Fairley, J. S. 1989. The food of otter *Lutra lutra* in the Irish Midlands and a comparison with that of mink *Mustela vison* in the same region. Proceedings of the Royal Irish Academy Section B-Biological Geological and Chemical Science 89: 33-46.

Lanszki, J. and Körmendi, S. 1996. Otter diet in relation to fish availability in a fish pond in Hungary. Acta Theriologica. 41: 127-136.

Le Jacques, D. and Lodé, T. 1994. L'alimentation de la Genette d'Europe, *Genetta genetta*, dans un bocage de l'ouest de la France. Mammalia 58: 383–393.

Levin, R. 1968. Evolution in changing environments: some theoretical explorations. New Jersey: Princeton University Press.

Livet, F., and Roeder, J.J. 1987. Encyclopédie des carnivores de France: la genette (*Genetta genetta*, Linnaeus, 1758). Société Française pour l'Étude et la Protection des Mammifères 17: 1–33.

Lodé, T., Lechat, Y. and Le Jacques, D. 1991. Le régime alimentarie de la Genette en limite Nord-Ouest de son aire de répartition. Revue D'Ecologie (Terre et Vie) 46: 339–348.

McDonald, R. A. 2002. Resource partitioning among British and Irish mustelids. J. Anim. Ecol. 71: 185-200.

Maran, T. and Henttonen, H. 1995. Why is the European mink disappearing? A review of the process and hypotheses. Annales Zooligici Fennici. 32: 47-54.

Maran, T., Kruuk, H., Macdonald, D.W. and Polma, M. 1998. The continuing decline of the European mink: evidence for intraguild aggression hypothesis. [In: Behaviour and ecology of riparian mammals: 297-323. Dunstone, N. and Gorman, M.L., eds.]. Symposium of the Zoological Societey of London.

Maran, T., Macdonald, D. W., Kruuk, H., Sidorovich, N. V. and Rozhnow, V. V. 1998. The continuing decline of the European mink *Mustela lutreola*: evidence for the intraguild aggression hypothesis. [In: Behaviour and ecology of riparian mammals. N. Dunstone and M. L. Gorman, eds.]. Cambridge, UK: Cambridge University Press.

Melero, Y., Palazón, P. and Gosàlbez, J. 2007. Morphological adaptation of an invasive American mink population in Mediterranean areas of Spain. Acta Zoologica (Stockh.), accepted.

Miranda, R. and Escala, M.C. 2002. Guía de identificación de restos óseos de los Ciprínidos presentes en España. Serie Zoológica 28. Pamplona: Publicaciones de Biología de la Universidad de Navarra.

Mitchell-Jones, A. J., Amori, G., Bogdanowicz, W., Kryštufek, B., Reijnders , P. J. H., Spitzenberger, F., Stubbe, M., Thissen, J. D. M., Vohralik, V. and Zima, J. 1999. Atlas of European Mammals. London: T and A D Poyser Ltd.

Palazón, S. 1998. Distribución, morfología y ecología del visón europeo (*Mustela lutreola* L. 1761) en la Península Ibérica. PhD thesis, Universitat de Barcelona.

Palazón, S. and Ruiz-Olmo, J. 1998. El visón europeo (*Mustela lutreola)* y el visón americano (*Mustela vison*) en España. ICONA, Madrid.

Palazón, S., Ruiz-Olmo, J, and Gosàlbez, J. 2006. Diet of European mink (*Mustela lutreola*) in Northern Spain and comparison with otter (*Lutra lutra*) and spotted genet (*Genetta genetta*) diets. Animal Biology Conservation, accepted.

Palomo, J. and Gisbert, J. 2002. Atlas de los Mamíferos Terrestre de España. Madrid: DGCNA-SECEM-SECEMU.

Pearson, L. 1985. Asymmetrical competition: are large animals competitively superior? Journal of Animal Ecology 71: 185-200.

Pianka, E.R. 1973. The structure of lizard communities. Annual Review of Ecological Systtems 4: 53-74.

Pikulik, M.M., Sidorovich, V.E., Jedrzejewska, B. and Jedrzejewski, W. 2001. Summer abundance and habitat distribution of frogs (*Rana temporaria*, *R. arvalis*, *R. kl. esculenta*), and toads (*Bufo bufo*) in the Bialowieza Primeval Forest, E Poland. Folia Zoologica 50: 65-74.

Rage, J.C. 1974. Batraciens fossiles du quaternaire. Bulletin de la Société linnéenne de Lyon 43: 276-289.

Ruiz-Olmo, J. 1995. Estudio bionómico de la nutria *Lutra lutra* en el nordeste de la Península Ibérica. PhD thesis, Universitat de Barcelona.

Ruiz-Olmo, J. and Aguilar, A. 1995. Els Grans Mamífers de Catalunya i Andorra. Barcelona: Lynx Edicions.

Ruiz-Olmo, J. and Delibes, M. 1998a. La nutria en España ante el horizonte del año 2000. Málaga: SECEM.

Ruiz-Olmo, J. and Delibes, M. 1998b. Conservation Plan for the otter in Catalonia: biology and ecology. Ministerio de Medio Ambiente. Environmental Notebook Documents nº 6. 145 pp.

Ruiz-Olmo, J., Jiménez, J. and Margalida, A. 1998. Capture and consumption of prey of the otter (*Lutra lutra*) in Mediterranean freshwater habitat of the Iberian Peninsula. Galemys 10: 209-226.

Ruiz-Olmo, J. and López-Martín, J.M. 1993. Note on the diet of the Common Genet (*Genetta genetta* L.) in mediterranean riparian habitats of N.E. Spain. Mammalia 57: 607-610.

Ruiz-Olmo, J., López-Martín, J.M. and Palazón, S. 2001. The influence of fish abundance on the otter (*Lutra lutra)* populations in Iberian Mediterranean habitats. Journal of Zoology 254: 325-336.

Ruiz-Olmo, J. and Palazón, S. 1997. The diet of otter (*Lutra lutra* L., 1758) in Mediterranean freshwater habitats. Journal of Wildlife Research 2: 171-181.

Ruiz-Olmo, J., Palazón, S., Bueno. F., Bravo, C., Munilla, I. and Moreno, R. 1997. Distribution, status and colonization of the American mink *Mustela vison* in Spain. Journal of Wildlife Research 2: 30-36.

Saavedra, D. 2003. Reintroduction of the Eurasian otter (*Lutra lutra)* in Muga and Fluvià basins (north-eastern Spain): viability, development, monitoring and trends of the new population. PhD thesis, Universitat de Girona.

Sidorovich, V. E. 1992. Comparative analysis of the diets of European mink (*Mustela luteola*) American mink (*M. vison*) and Polecat (*M. putorius*) in Byelorussia. Small carnivore conservation 6: 2-4.

Sidorovich, V.E. 1997. Mustelids in Belarus. Evolutionary ecology, demography and interspecific relationships. Minsk: Zolotoy Uley.

Sidorovich, V.E. 2000. Seasonal variation in the feeding habits of riparian mustelids in river valleys of NE Belarus. Acta Theriologica 45: 233-242.

Sidorovich, N. V., Macdonald, D. W., Kruuk, H. and Krasko, D. A. 2000. Behavioural interactions between the naturalized American mink *Mustela vison* and native riparian mustelids, NE Belarus, with implications for population changes. Small Carnivore Conservation 22: 1-5.

Sidorovich, V. and Macdonald, D. W. 2001. Density dynamics and changes in habitat use by the European mink and other native mustelids in connection with the American mink expansion in Belarus. Netherlands Journal of Zoology 51: 107-126.

Sidorovich, V. E. 1992. Comparative analysis of the diets of European mink (*Mustela luteola*) American mink (*M. vison*) and Polecat (*M. putorius*) in Byelorussia. Small carnivore conservation 6: 2-4.

Sidorovich, V., Kruuk, H. and Macdonald, D.W. 1999. Body size and interactions between European and American mink in Eastern Europe. Journal of Zoology 248: 521-527.

Teerink, B.J. 1991. Hair of West-European mammals. Cambridge: Cambridge University Press.

Virgós, E., Llorente, M. and Cortés, Y. 1999. Geographical variation in genet (*Genetta genetta* L.) diet: a literature review. Mammal Review 29: 119-128.

Wiens, J. A. 1989. The Ecology of Bird Communities: Processes and variations. Cambridge, UK: Cambridge University Press.

Wise, M.H., Linn, I.J. and Kennedy, C.R. 1981. A comparison of the feeding biology of mink *Mustela vison* and otter *Lutra lutra*. Journal of Zoology 195: 181-213.

Table 1 Number of individuals captured, their mean weight in grams, and standard deviation of the weight of prey species obtained from our own field study. In the case of fish, weight was estimated by measuring the size of pharyngeal teeth and vertebrae (see methods).

	Field data			
	Spring-summer		Autumn-winter	
Species	Number	Weight	Number	Weight
Apodemus sylvaticus	46	22.47 (± 5.48)	26	16.80 (± 4.17)
Mus musculus	73	11.67 (± 3.17)	49	12.98 (± 1.52)
Crocidura russula	30	7.73 (± 2.02)	14	8.23 (± 0.95)
Barbus graellsii	164	90 (± 30.12)	15	100 (± 29.32)
Chondrostoma miegii	34	7.1 (± 1.86)	36	8.1 (± 1.52)
Ciprinus carpio	4	35 (± 2.12)	2	33 (± 1.85)
Salmo trutta	7	200 (± 32.22)	3	200 (± 10.08)
Rutilus rutilus			1	1.5
Procambarus clarkii	10	13 (± 3.02)	10	13 (± 2.11)

Table 2 Diet composition of the American mink *Mustela vison* in spring-summer (April 1 - September 30) and autumn-winter (October 1 – March 30) in Catalonia, Spain. FR – frequency of occurrence; RFO – relative frequency of occurrence; B – percentage of biomass consumption; P = present in < 0.1. * except *P. clarkii.*

Item	Spring-summer			Autumn-winter		
	FO	RFO	B	FO	FRO	B
Arvicola sapidus	0.8	0.7	4.1	0.5	0.4	1.8
Apodemus sylvaticus	1.7	1.4	1.2	2.5	2.1	1.0
Mus musculus	4.6	3.8	1.7	3.5	2.9	1.1
Rattus sp.	-	-	-	0.5	0.4	1.8
Crocidura russula	1.2	1.0	0.3	-	-	-
Unidentified mammals	4.1	3.5	8.8	1.5	1.3	2.3
Total mammals	9.5	10.4	16.1	6.9	7.2	8.0
Anas platyrhynchos	1.7	1.4	10.8	8.9	7.6	43.0
Passeriformes	-	-	-	2.00	1.7	3.1
Unidentified birds	0.8	0.7	1.8	-	-	-
Total birds	2.5	2.1	12.5	10.9	9.3	46.1
Barbus graellsii	4.6	3.8	13.3	4.5	3.8	10.8
Chondrostoma miegii	1.2	1.0	0.3	3.0	2.5	0.6
Ciprinus carpio	1.7	1.4	1.9	2.0	1.7	1.7
Salmo trutta	1.7	1.4	10.8	-	-	-
Unidentified fish	2.5	2.1	8.1	2.5	2.1	6.0
Total fish	11.6	9.7	34.4	11.9	10.2	19.0
Procambarus clarkii	87.2	73.3	37.0	85.6	73.3	26.9
Gasteropoda	0.8	0.7	P	-	-	-
Arácnida	0.4	0.4	P	-	-	-
Miriapoda	0.4	0.4	P	-	-	-
Hymenoptera	1.7	1.4	P	-	-	-
Coleoptera	0.8	0.7	P	-	-	-
Unidentified insects	1.2	1.0	P	-	-	-
Total invertebrates*	2.1	4.5	P	-	-	-
Total number scats^1 or prey^2	242^1	288^2		202^1	236^2	

Table 3 Diet composition of the spotted genet *Genetta genetta* in spring-summer (1 April-30 September) and autumn-winter (1 October-30 March) in Catalonia, Spain. FR – frequency of occurrence; RFO – relative frequency of occurrence; B – percentage of biomass consumption; P = present in < 0.1. * except *P. clarkii.*

Item	Spring-summer			Autumn-winter		
	FO	RFO	B	FO	FRO	B
Arvicola sapidus	1.7	1.4	10.2	-	-	-
Apodemus sylvaticus	1.7	1.4	1.5	5.7	4.4	2.3
Mus musculus	7.1	6.1	3.4	7.1	5.5	2.3
Rattus sp.	-	-	-	2.9	2.2	10.0
Crocidura russula	2.1	1.8	0.7	1.4	1.1	0.3
Unidentified mammals	1.3	1.1	3.3	2.9	2.2	4.4
Total mammals	13.8	11.6	18.4	20.0	15.4	19.1
Anas platyrhynchos	2.1	1.8	17.1	-	-	-
Passeriformes	-	-	-	4.3	3.3	6.5
Unidentified birds	-	-	-	4.3	3.3	6.5
Total birds	2.1	1.8	17.0	8.6	6.6	13.1
Barbus graellsii	1.3	1.1	4.6	17.1	13.2	40.2
Chondrostoma miegii	0.4	0.4	0.1	-	-	-
Salmo trutta	1.3	1.1	10.2	-	-	-
Unidentified fish	-	-	-	1.4	1.1	3.4
Total fish	2.5	2.5	14.9	17.1	14.3	43.5
Procambarus clarkii	92.1	79.2	48.9	80.0	61.5	24.4
Gasteropoda	0.4	0.4	P	-	-	-
Hymenoptera	1.3	1.1	P	-	-	-
Coleoptera	2.5	2.2	P	2.9	2.2	0.02
Hexapoda	0.4	0.4	P	-	-	-
Total invertebrates*	2.5	3.9	P	2.9	2.20	0.02
Unidentified reptiles	0.4	0.4	P	-	-	-
Total number of scats[1] or prey[2]	240[1]	279[2]		70[1]	91[2]	

Table 4 Diet composition of the Eurasian otter *Lutra lutra* in spring-summer (1 April-30 September) and autumn-winter (1 October-30 March) in Catalonia, Spain. FR – frequency of occurrence; RFO – relative frequency of occurrence; B – percentage of biomass consumption; P = present in < 0.1.

Item	Spring-summer			Autumn-winter		
	FO	RFO	B	FO	FRO	B
Mus musculus	1.4	1.2	0.2	-	-	-
Crocidura russula	1.4	1.2	0.1	-	-	-
Total mammals	2.8	2.4	0.3	-	-	-
Anas platyrhynchos	1.4	1.2	3.2	-	-	-
Barbus graellsii	62.5	53.6	72.8	45.7	34.4	54.4
Chondrotoma miegii	12.5	10.7	1.1	43.5	32.8	4.2
Ciprinus carpio	-	-	-	2.2	1.6	0.9
Salmo trutta	-	-	-	4.4	3.3	10.4
Rutilus rutilus	-	-	-	2.2	1.6	P
Unidentified fish	13.9	11.9	17.8	23.9	18.0	28.5
Total fish	75.0	76.2	91.8	89.1	91.8	98.3
Procambarus clarkii	27.8	17.9	3.4	10.9	8.2	1.7
Gasteropoda	1.4	1.2	P	-	-	-
Natrix maura	1.4	1.2	1.3	-	-	-
Total N^1 scats or prey^2	72^1	84^2		46^1	61^2	

Table 5 Niche breadth (B) and niche overlap (α) of mink, genet and otter in spring-summer and autumn-winter in Catalonia, Spain. All prey items were included in the calculations.

		Spring-summer			Autumn-winter		
		M. vison	*G. genetta*	*L. lutra*	*M. vison*	*G. genetta*	*L. lutra*
B		0.16	0.11	0.13	0.16	0.27	0.03
α	*M. vison*	-	0.37	0.17	-	0.33	0.12
	G. genetta	-	-	0.14	-	-	0.15

Figure 1 Location of the study area.

Figure 2 Comparison of mink, genet and otter diets for spring-summer and autumn-winter in Catalonia, Spain. Six categories of prey are expressed as relative frequency of occurrence (RFO).

Figure 3 Comparison of mink, genet and otter diets for spring-summer and autumn-winter in Catalonia, Spain. Six categories of prey are expressed as percentage of biomass consumption (B).

Figure 4 Relationships between the relative frequency of occurrence (RFO) of small mammals in the diet of the American mink (a) and spotted genet (b) and the number of small mammals trapped. The regression equation and the regression coefficient (r^2) are shown. Round points represent the three different mammal species in spring-summer while the squared points represent the same mammal species in autumn-winter.

Figure 1.

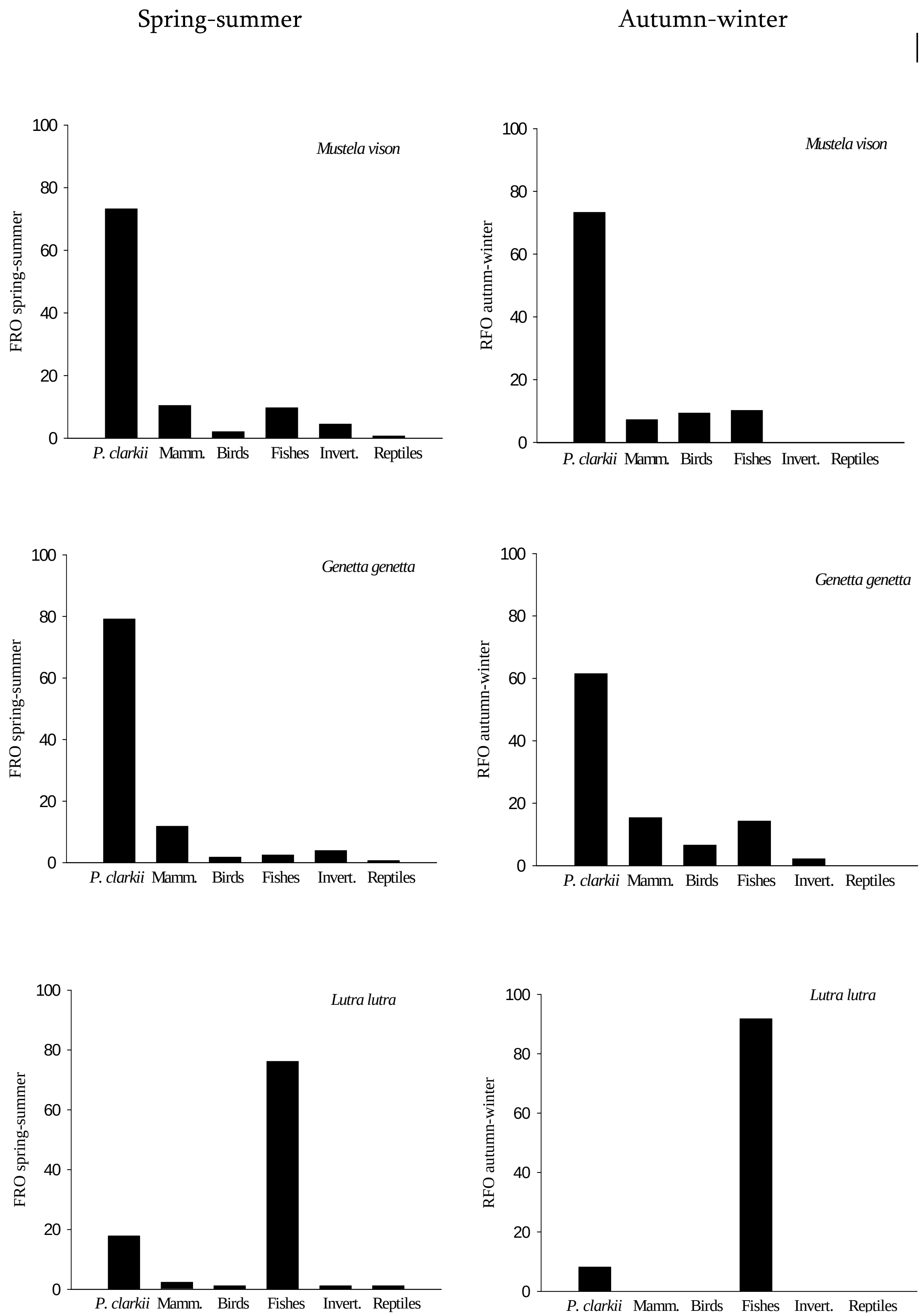
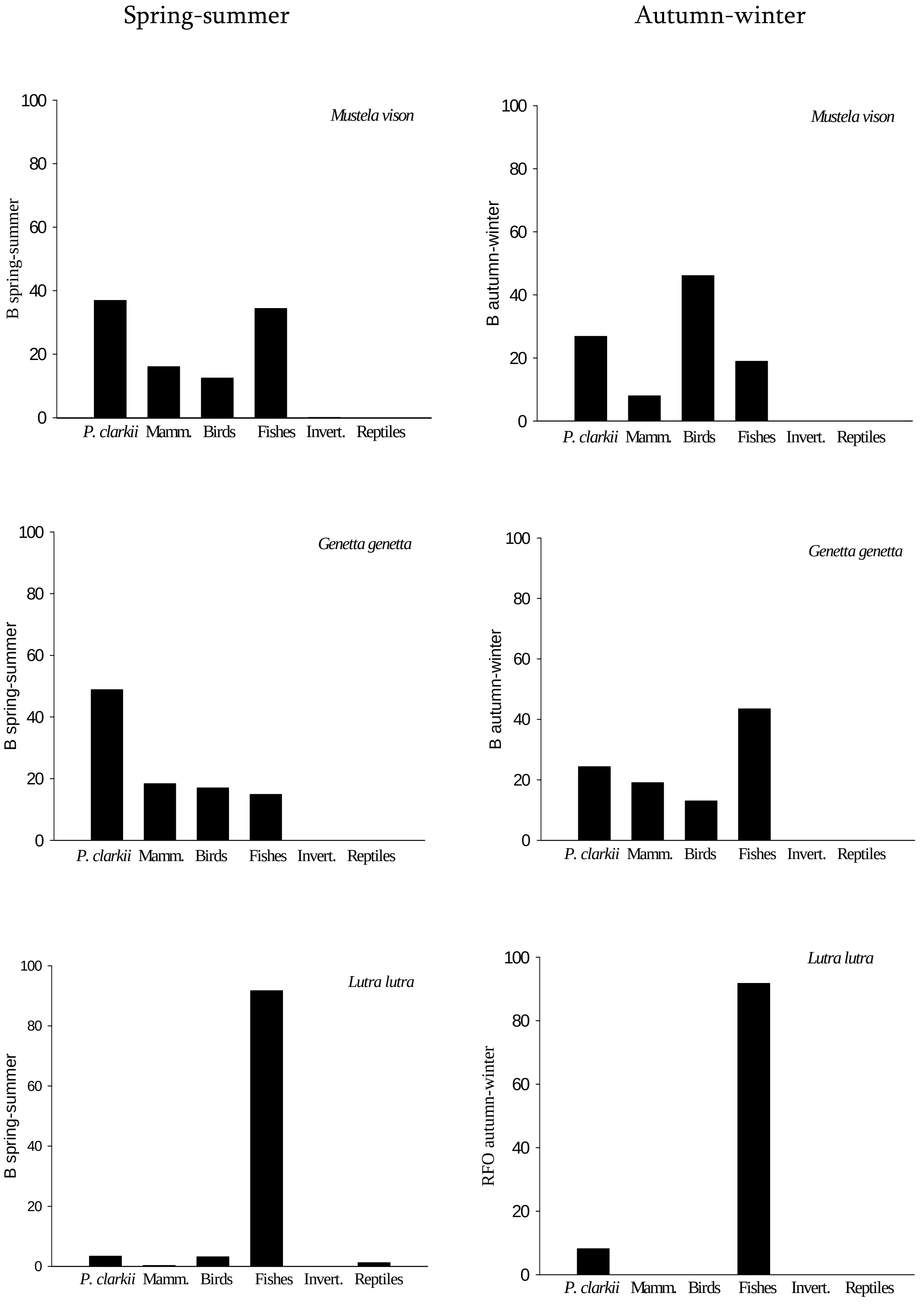

Spring-summer
Autumn-winter
Mustela vison
FRO spring-summer
RFO autmn-winter
Genetta genetta
FRO spring-summer
RFO autumn-winter
Lutra lutra
FRO spring-summer
RFO autumn-winter
0
20
40
60
80
100
P. clarkii
Mamm.
Birds
Fishes
Invert.
Reptiles

Figure 2.



Spring-summer

Autumn-winter

igure 3.

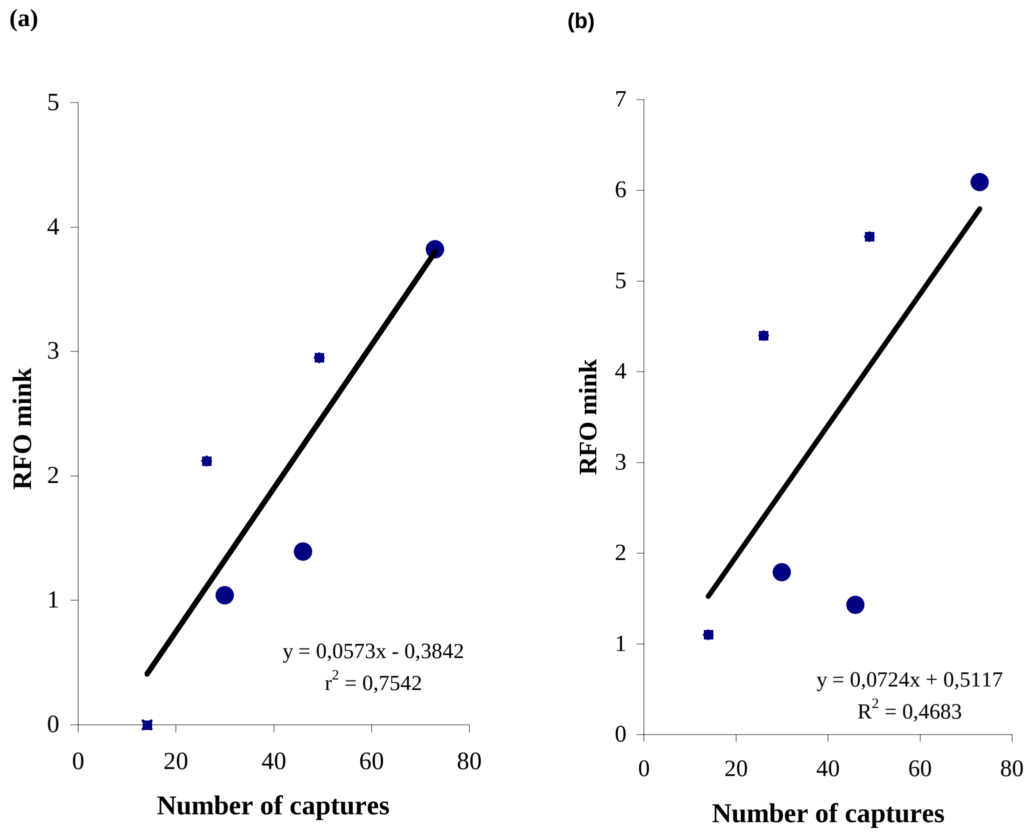

(a)
5
4
3
2
1
0
RFO mink
0
20
40
60
80
Number of captures
y = 0,0573x - 0,3842
r² = 0,7542
(b)
7
6
5
4
3
2
1
0
RFO mink
0
20
40
60
80
Number of captures
y = 0,0724x + 0,5117
R² = 0,4683

Figure 4.

RESUMEN

La competencia entre especies simpátricas aparece cuando las especies explotan los mismos recursos o recursos parecidos (Wiens, 1989). Es decir, cuando existe un solapamiento de nicho ya sea trófico y/o espacial. Esta competencia interespecífica puede actuar como un mecanismo de control de poblaciones de una especie sobre otra, ya que se produce una competencia por unos recursos que son limitados.

El presente trabajo tiene como objetivo comprobar la posible existencia de competencia interespecífica entre el visón americano, la nutria y la jineta por los recursos tróficos. En el estudio se describe la dieta del visón americano y la de sus posibles competidores potenciales presentes en la zona de estudio, la nutria y la jineta. Se ha analizado la amplitud de nicho trófico, el solapamiento entre la dieta de las tres especies y los posibles cambios estacionales en la composición de sus respectivas dietas.

El estudio se realizó a lo largo de 20 km del río Llobregat y a lo largo de 12 km de su afluente la riera Gavarresa. Se analizaron 444 excrementos de visón, 310 de jineta y 108 de nutria, recolectados entre los años 2002 y 2005 durante primavera-verano (1 abril – 30 septiembre) y otoño-invierno (1 octubre – 30 marzo). Tras la separación de las muestras por especies y su lavado, se procedió a la determinación de las presas encontradas. La composición de las dietas se ha expresado como frecuencia de ocurrencia (FO), frecuencia relativa de ocurrencia (RFO) y porcentaje de biomasa consumida (B) (Conroy *et al.*, 1993). En el análisis estadístico, se ha sometido a comprobación la existencia de posibles diferencias estacionales mediante el test U-Mann Whitney. Finalmente, la amplitud de nicho trófico se ha calculado empleando

la estandarización de Hurlbert para el índice de Levin (Hurlbert, 1978; Levin, 1968); y el solapamiento de nicho, mediante la adaptación de Pianka para el índice de Levin (Pianka, 1973).

Los resultados obtenidos muestran que la presa más consumida (RFO) por el visón americano es el cangrejo de río americano (*Procambarus clarkii*), seguido de micromamíferos y peces durante primavera-verano, y de aves y micromamíferos durante otoño-invierno (Tabla 2; Fig. 1). Sin embargo, en términos de B el cangrejo de río y los peces constituyen la base energética del visón durante primavera-verano, y las aves durante otoño-invierno (Tabla 2; Fig. 2). En el caso de la jineta, el cangrejo de río, seguido de los micromamíferos, son las presas más consumidas (RFO) durante primavera-verano. Durante otoño-invierno su dieta se diversifica incluyendo a las aves y a los peces también como presas importantes (Tabla 3; Fig. 1). En términos de B, el cangrejo de río constituye la mayor fuente de energía durante primavera-verano, y los peces durante otoño-invierno (Tabla 3; Fig. 2). En lo que concierne a la nutria, presenta una dieta cuyo mayor componente son los peces, tanto en relación a la RFO como a B y en ambas épocas de muestreo; en ningún caso hay diferencias estacionales significativas. Existe una dependencia entre RFO y número de micromamíferos capturados en el caso del visón pero no en el de la jineta.

El solapamiento entre los diferentes nichos tróficos es mayor entre el visón y la jineta que entre el visón y la nutria. Asimismo, el solapamiento entre jineta y nutria es menor que entre jineta y visón (Tabla 5).

A pesar de presentar composiciones de dieta similares, el solapamiento de nicho trófico es bajo entre el visón y la jineta (37% durante primavera-verano y 33% durante otoño-invierno) aunque mayor que entre la nutria y el visón. Actualmente, parece que la interferencia entre el visón y la jineta o la nutria en la zona de estudio es lo suficientemente baja como para poder pensar que el solapamiento que se detecta entre sus respectivos nichos tróficos no representa un problema para la población de visón americano. Sin embargo, y teniendo en cuenta las bajas densidades poblacionales de la nutria en la zona, es probable que un aumento de esta especie pudiera provocar en el futuro una mayor presión de competencia sobre el visón. Ruiz-Olmo (1997) ha demostrado que la nutria puede reducir la expansión del visón americano en España. Consecuentemente, cabe concluir que la recuperación de la nutria en los sistemas fluviales ibéricos es clave tanto para la conservación de dicha especie como para el control de las poblaciones de visón americano.

Space use and habitat preferences of the invasive American mink in a Mediterranean area*

Yolanda MELERO[1*], Santiago PALAZÓN[1,2], Eloy REVILLA[3], Joana MARTELO[4] and Joaquim GOSÀLBEZ[1].

[1]Department of Animal Biology (Vertebrates). University of Barcelona. Av. Diagonal, 645. 08028. Barcelona, Spain.
[2]Department of Environment and Housing. Generalitat de Catalunya. Doctor Roux, 80. 08017. Barcelona, Spain.
[3]Department of Conservation Biology. Estación Biológica de Doñana, Spanish Council for Scientific Research-CSIC. Avenida Maria Luisa, s/n. Pabellón del Perú. 41013. Sevilla, Spain.
[4]Rua São Joãa de Deus, 1. 7600-033. Aljustrel, Portugal.

* Correspondence to address:
Yolanda MELERO. Departament de Biologia Animal (Vertebrats). Universitat de Barcelona. Av. Diagonal, 645. 08028. Barcelona, Spain.
Telephone number: (0034) 676967427. Fax number: (0034) 934034426
E-mail: yolrem@gmail.com.

Second authors' e-mail addresses:
Santiago PALAZÓN: santiago.palazon@gencat.net
Eloy REVILLA: revilla@ebd.csic.es
Joaquim GOSÀLBEZ: jgosalbez@ub.edu

---

* Biological Conservation, under review.

Space use and habitat preferences of the invasive American mink in a Mediterranean area

Abstract

Space use, intra-territorial habitat preferences and factors affecting both were studied in an invading population of American mink, *Mustela vison* in a Mediterranean area of Spain. Average linear home range was 1.19 ± 0.73 km (± SD) and core area was 0.21 ± 0.08 km for resident males (n = 10); while for females (n = 5) they were 0.54 ± 0.14 km and 0.19 ± 0.11 km, respectively. Overlapping between the home ranges of residents was low. In no case their core areas overlapped. Home ranges were small in comparison to other study areas and in general the resident minks were territorial. Linear home range length was related to individual weight and to the river. Weight had a positive effect indicating a potential body condition effect, while river may be showing a habitat quality effect. Habitat preferences were positively affected by the abundance of helophytic vegetation and negatively by the presence of human activity. Helophytic vegetation offers both food and refuges, while human activity may represent a potential danger. Percentage of captures was higher inside the core areas and was slightly influenced positively by abundance of helophytic vegetation. All this information should be considered when designing and implementing measures to control the expansion of American mink. We recommend keeping going with the trapping sessions but, given the results obtained, reducing the distance between traps down to 200 m to maximize capturability (i.e. about doubling the trapping effort), and, when available, placing them near helophytic vegetation. In the absence of helophytic vegetation, traps should be located near any kind of vegetation providing coverage for mink, and far from human activity.

Key words: *Mustela vison*, home range, habitat selection, control management, Spain.

Running Head: Space use and habitat preferences of American mink

Introduction

The American mink (*Mustela vison*) has become a serious conservation problem in Europe, Russia and South America since its introduction for fur farming. The species has an impact on wildlife, game species and livestock. It can reduce and locally exterminate potential prey such as watervoles *Arvicola terrestris* (Strachan and Jefferies, 1993; Barreto *et al.*, 1998; Macdonald and Strachan, 1999), or birds (Nordström and Korpimäki, 2004; Craik, 1999; Ferreras and Macdonald, 1999). Moreover, it seems that it is outcompeting some of the remaining populations of European mink (Maran *et al.* 1998), one of the most endangered mammals in Europe (International Union for Conservation of Nature and Natural Resources, 2003). In Europe, some governments are currently developing control programmes to eradicate the invading populations in order to protect the native prey and the European mink. Since 1999 Spain has a programme founded by different regional governments, the central government, and the European Union to control the American mink and to protect the European mink (European Life Programs: 02MNAT/8604, 00NAT/E/7299, 00NAT/E/7335 and 00NAT/E/7331 2001-2008; MMA 2006). Currently, in Spain, several trapping seasons have been made placing the traps along reaches and located at a distance of 300-500 m from each other on both river banks and checked daily. To reduce its establishment and its spread we need to improve the efficiency of trapping and hence it is important to know the patterns of space use and the habitat requirements affecting the establishment of this species.

The American mink is commonly associated with vegetated areas adjacent to water (Dunstone, 1993) exploiting inland waterways and coastal habitats (Dunstone and Birks, 1983). American mink may establish in its natal territory or after natal dispersal. Once established, it holds the territory until death when the space becomes available for new individuals (Macdonald and Rushton, 2003). Its linear home range is between 1 and 8.6 km of rivers' length (Birks, 1986; Dunstone, 1993; Yamaguchi and Macdonald, 2003). Several factors can affect the patterns of space use of mustelids. For example, home range size can vary seasonally depending on the availability of resources (Erlinge and Sandell, 1986; Robitaille and Raymond, 1995). As occurs with other small mustelid species (Sandell, 1989), the mink shows intrasexual territoriality; with males having larger home ranges than females, and with male territories encompassing those of females (Dunstone, 1993). Moreover, mink defend its own territory against individuals of the same sex during the non-breeding season (Gerell, 1970; Birks, 1981; Ireland, 1990; Dunstone, 1993), abandoning its territory to roam over larger areas looking for females during the breeding season (Ireland, 1990; Dunstone, 1993).

American mink may also need particular habitat features to establish its home range, survive and breed. The space use is related to vegetation types and vegetation density, presence of water, pollution, and to the availability and distribution of food and dens (Gerell, 1970; Erlinge, 1972; Birks, 1981; Birks and Linn, 1982; Dunstone and Birks, 1983; Clode and Macdonald, 1995; Halliwell and Macdonal, 1996; Loukmas, 1998; Loukmas and Halbrook, 2001; Yamaguchi *et al.*, 2003).

In this paper we describe the patterns of space use and intra-territorial habitat requirements of an invasive population established in a Mediterranean area. Studies of Mediterranean populations are scarce but important since mink behaviour can differ from other areas due to differences in natural conditions and in the types and availability of habitat and food resources. We present data on home range and core area sizes, and overlap and investigate the relationship between home ranges and core area size and sex, age and weight. We also describe the relation between the number of radiolocations per river section and habitat variables.

2. Material and methods

2.1. Study area

The study area was located in Catalonia, Spain (1º 53'N, 41º 49' E) along the rivers Llobregat (6 km) and its tributary Gavarresa (5 km). The average annual rainfall is 490 mm approximately, while the altitude ranges between 160 m and 350 m. The riparian forest is dominated by *Arundo donax*, *Typha latifolia*, *Phragmites communis*, *Juncus* spp., *Rubus ulmifolius*, *Populus alba* and *Salix* spp. As a Mediterranean area, summers are dry, while autumns are characterised by strong rainfalls with the subsequent flooding that reduce vegetation coverage yearly.

Main competitors sharing the riparian habitat with *M. vison* are the river otter (*Lutra lutra*), the genet (*Genetta genetta*) and the stone marten (*Martes foina*). Main potential preys are several species of Cyprinids (*Cyprinus carpio*, *Barbus graellsii*), Salmonids (*Salmo trutta*), the American crayfish (*Procambarus clarkii*) and rodents (*Mus musculus*, *Apodemus sylvaticus* and *Arvicola sapidus*).

2.2. Mink trapping

One trapping session of 588 trap-nights was conducted annually in 2003, 2004 and 2005. The sessions were set each year between October and December at both rivers. Animals were live-trapped in single cage traps (15 x 15 x 60 cm) located on both riverbanks at a distance of 300-400 m, and checked every day. After immobilization with 0.15 ml of ketamine (Imalgéne, Rhone Merieux, Lyon, France) and 0.03 ml of medetomidine (Domtor, Pfizer SA, Madrid, Spain), the captured animals were manipulated and classified as either a new capture or a recapture. Trapping was carried out during the post breeding season when all animals were older than 5 months and there were no juvenile minks (<4 months old). Individuals were classified by sex and age (subadults 5-8 months old; or adults >8 months old) based on the combination of teeth condition and weight (Maran and Robinson, 1996). Captured animals were individualised with a transponder (Trovan Ltd., Madrid, Spain). Once fully recovered all animals were released in the same area where they had been captured.

2.3. Radiotracking

Several captured animals were marked with waterproof radiotransmitters fitted with collar necks (frequency 150 and 151 MHz, Biotrack, Ltd., Wareham, Dorset, UK and and Tinyloc Ltd., Mataró, Spain). Radiocollars weighted approximately 15 g, less than 3% of the lightest adult mink captured during the study (510 g). Signal was received using receiver model TR4 (Telonics Ltd., Mesa, Arizona, USA) and multidirectional or bidirectional antennas. Radiolocations were recorded by homing to the animals (U.T.M. positions, using a Garmin GPS, Romsey, Hampshire, UK) without triangulation since mink movements follow the river course (Gerell, 1970; Birks and Linn, 1982; Ireland, 1990; Bonesi, 1996). Animals were radiotracked until transmitters stopped working, being the latest locations in early March. Radiotracking was made daily every hour unless it took longer to find the animal. Additionally, 24 h radiotracking periods were made taking a location every 30 minutes.

2.4. Habitat description

The most obvious habitat characteristics that can affect mink space use are rivers and associated vegetation types as the species does not tend to move far away from water courses (Ireland, 1990). Rivers were divided in approximately 100 m long sections and the following variables were measured in each section: river depth, river width, abundance of vegetation and presence of human activity. River depth was taken in the mid of each 100 section; at each mid point depth was measured in three points along the river width (50 cm of each shoreline and in the middle width). River width was also calculated in the mid point of 100 sections. Vegetation type was recorded along the shoreline and classified into four types: grass, helophytic vegetation, shrub and trees. The abundance of each type was ranked according to its cover between 0 (coverage 0-10%) and 5 (coverage 75-100%). Presence of human activity was taken into account if it was on the shoreline (0-2 m) or in the riparian forest (minimum 2 m from water) and it was set as 0 (absence), 1 (agriculture activity) and 2 (industrial activity).

2.5. Radiotracking and capture data analysis

Birks and Linn (1982) reported that mink radiotracked at least twice a day revealed more than 80% of their total home range in < 5 days, and the entire home range in < 10 days. Therefore, only individuals tracked for either ≥ 5 days were included. Only locations separated by at least two hours were used to calculate home ranges. We consider this time enough to remove temporal correlation between consecutive locations because in our study area it takes about 2 hours for a mink to cover its entire home range. Among successive inactive fixes only one location was picked up for analysis. Resident and transient minks were distinguished based on their spacing patterns. Transients did not stay in any area for more than 10 consecutive days and moved. Home ranges (99%) and core areas (areas with the 50% of the fixes) were calculated as kernel home range using the extension Animal Movement SA v.2.04 beta from the program ArcView GIS 3.2 (Enviromental System Research Institute, Inc., USA) and afterwards linear home range was calculated based on the linear distance of waterway included in the kernel. A generalised linear mixed model (GLMM) was used to analyse the influence of factors on linear home range and on linear core area. Sex, weight, age, river, and the interaction of number of tracking days and number of radiolocations were set as possible fixed factors affecting the spacing pattern of resident minks. Year and individual were set as random.

Overlapping between mink ranges was defined as length of river shared between two minks, calculated using ArcView GIS 3.2 (Enviromental System Research Institute, Inc., USA), expressed as the percentage of the total home range shared per individual. The effect of sex, age and status on the percentage of overlapping was studied using a GLMM. Year and individual were set as random effects.

Percentage of captures inside the core areas, inside the rest of the home ranges, and outside the home ranges were calculated for captures of resident minks.

2.6. Habitat data analysis

Since vegetation types are correlated, we decided to select those that offer coverage for mink and then that are biologically more important: helophytic vegetation and shrub. River width and depths are also correlated variables, so they were joined in a new variable called river section (area of the polygon draw from river width and river depths). Habitat preferences of radiotracked minks were analyzed using the percentage of radiolocations per each 100 m river section. Percentage of radiolocations of each resident individual was calculated and then summed for each 100 m river section. Therefore we had the percentage of total radiolocations in each river section. The influence of the habitat variables on the percentages was tested using a GLMM. Habitat variables were set as fixed effects; year and individual were set as random effect.

Percentage of captures per each river section was also obtained and the influence of the habitat variables on the percentage tested using a GLMM. We remove human activity from the analysis because most of the traps were located close to agriculture fields. Habitat variables were also set as fixed effects; year and individual were set as random effects.

All statistical analyses were carried out using SAS statistical package version 9.1 (SAS Institute Inc., Cary, NC, USA) and SPSS version 12.0 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Mink trapping

A total of 58 captures were obtained, in which 50 minks and 8 recaptured minks were trapped: 26 in 2003, 16 in 2004 and 8 in 2005. Overall 35 minks were marked with transmitters, 18 of them provided enough information to study their home range (5 from 2003, 9 from 2004 and 4 from 2005) (Table 1). The rest of them lost the collar or were lost after being released due to collar failure before having enough radiolocations. Female F1 was the only mink trapped and marked two consecutive years (in the same trap). However, in the second year we could not obtain enough data. The other radiotracked minks were new individuals each year.

3.2. Status and home range

All radiotracked animals stayed closer than 10 m to the nearest water source. The mean linear home range (± SD) size of adult resident males was 0.89 ± 0.46 km and 0.21 ± 0.09 km of core area (n = 7); mean home range of adult resident females was 0.61 ± 0.14 km and 0.21 ± 0.14 km (n = 3) of core area (Table 1, Fig. 1). Both resident males and females had between 1 and 3 core areas inside their home range (Fig. 1). The mean home range size in the of subadult resident males was 0.82 ± 0.17 km and 0.20 ± 0.04 km of core area (n = 3); mean home range of subadult resident females was 0.43 ± 0.01 km and 0.14 ± 0.01 km of core area (n = 2).

There was intrasexual and intersexual overlap between resident minks (Table 1, Fig. 1a, d, and g). However, overlap was no different between sexes (F = 0.35, df = 1, P = 0.56), and neither between ages (F = 0.51, df = 1, P = 0.48). The overlap was larger between the home range of the residents and those of transients than between residents (F = 10.56, df = 1, P = 0.03) (Table 1, Fig. 1c and f). Mink M12 was not included in the overlapping analysis because the individual was found dead before

M13 and F5 were trapped, therefore overlapping may not have occurred between them. Nevertheless, core areas never overlapped (Fig. 1b, e and h).

Resident minks were captured with higher frequency inside the core areas (66.67 %) than inside the home ranges but outside the core areas (33.33 %), ($\chi^2 = 5.71$, df = 1, $P < 0.025$). There were no mink captured outside their home ranges.

3.3. Factors affecting home range and core area size

We found heavier minks showed a tendency to have larger home range sizes than lighter minks ($F = 8.44$, df = 1, $P = 0.017$). Mean home range size for Llobregat was 0.83 ± 0.44 km (n = 9), and for Gavarresa it was 0.65 ± 0.16 km. Differences between home ranges located in each river were significant ($F = 5.94$, df = 1, $P = 0.02$). Sex ($F = 0.42$, df = 1, $P = 0.53$), age ($F = 2.07$, df = 1, $P = 0.18$) and the interaction between tracking days and the number of radiolocations ($F = 0.12$, df = 1, $P = 0.73$) were not significant for home range size. No factor was found significant in the case of the core area size analysis ($F < 8.44$, $P > 0.17$ in all cases).

3.4 Habitat preferences inside the home range

Mean number of radiolocations found for the ranks of helophytic vegetation were: 0.10 % (n = 1 river section) for rank 1; 2.77 ± 0.33 % (n = 2) for rank 2; 0.79 ± 0.97 % (n = 29) for rank 3; 1.16 ± 1.81 % (n = 29) for rank 4; and 1.59 ± 2.04 % (n = 24) for rank 5. Sections with rank 0 (0-10% of vegetation cover) did not have any radiolocation. In the case of shrub, results were as follow: 1.05 ± 1.40 % (n = 13) for rank 0; 3.57 ± 3.43 % (n = 4) for rank 1; 0.64 ± 1.43 % (n = 9) for rank 2; 0.96 ± 1.67 % (n = 26) for rank 3; 1.63 ± 1.38 % (n = 22) for rank 4; and 0.46 ± 0.81 % (n = 11) for rank 5. Mean number of radiolocations in the case of human activity were 1.24 ± 1.40 % (n = 11) for rank 0; 0.99 ± 1.36 % (n = 63) for rank 1; and 2.15 ± 2.87 % (n = 11) for rank 3.

The GLMM analysis found that abundance of helophytic vegetation had a positive effect on the percentage of radiolocations per section (F = 3.45, df = 5, P = 0.007), while presence of human activity had a negative effect (F = 3.18, df = 2, P = 0.047). Abundance of shrub (F = 0.69, df = 5, P = 0.63) and river section (F = 1.94, df = 1, P = 0.17) had no effect on the number of radiolocations per transect.

Core areas presented a mean rank of 4 ± 1 (n = 35) for abundance of helophytic vegetation, and 3 ± 1 (n = 35) for abundance of shrub. Home ranges outside the core area presented a mean rank of 3.6 ± 1 (n = 50) for abundance of helophytic vegetation, and 2.7 ± 2 (n = 50) for abundance of shrub.

Percentage of captures, of the total of 58 captures, for each rank of helophytic vegetation was: 10.34 % (n = 6) for rank 0; 3.45 % (n = 2) for rank 1; 6.89 % (n = 4) for rank 2; 17.24 % (n = 10) for rank 3; 29.31 % (n = 17) for rank 4; and 32.76 % (n = 19) for rank 5. In the case of shrub, results were as follow: 18.96 % (n = 11) for rank 0; 27.59 % (n = 16) for rank 1; 13.79 % (n = 8) for rank 3; and 39.65 % (n = 23) for rank 5. Sections with rank 2, 4, and 6 did not have any capture. No factor (abundance of helophytic vegetation, abundance of shrub and river section) was significant (F < 0.87, P > 0.53 in all cases).

4. Discussion.

4.1. Home ranges and spacing pattern

American mink inhabits long linear home ranges confined to a narrow ribbon of riparian habitat (Ireland, 1990; Bonesi, 1996) and that can vary in size depending on its adaptations to different environments. Birks and Linn (1982) found a mean home range length of 4.5 km for males and 2.85 km for females in UK; Gerell (1970) found 2.13 km for males and 1.85 km for females in Sweden; Palazón and Ruiz-Olmo. (1995) observed a female home range size of 2.9 km in Spain; Yamaguchi and Macdonald (2003) obtained a mean of 6.8 km for males and 2.7 km for females in the United Kingdom. Meanwhile, in its original environment of North America, results were higher showing a mean of 11.08 km for males and 5.63 km for females (Stevens *et al.*, 1997). Apart from Palazón and Ruiz-Olmo (1995), the studies were made all the year round so that comparisons with our results are difficult. However, Yamaguchi and Macdonald (2003) did not find seasonal differences for female's home ranges and males are supposed not to hold their territory during the breeding season (Dunstone, 1993). Therefore, seasonal variations may not be the only reason for the differences between studies. Variation might be caused by differences in prey availability in each environment since animals are expected to utilise home ranges that are “minimum economically defensible” areas (Gill and Wolf, 1975), but which are large enough to satisfy their metabolic needs over time (McNab, 1963). In our study, the area holds a high population of the invasive American crayfish, *Procambarus clarkii*, which is the main prey item in the American mink diet (Melero *et al.*, submitted). This prey in combination with small mammals, fishes and birds provide high prey availability for minks in their small home ranges.

Although we found home ranges of some resident minks of the same sex overlapping, the length of overlap was small, thus showing a clear pattern of territoriality. Sandell (1989) and Garin *et al.* (2002) also found exclusivity of home ranges for the American and European mink, respectively. Territoriality, thought, can be broken due to a dynamic behaviour of the individuals trying to expand their territories. An example of this was the overlapping between the American minks of the same sex found by Yamaguchi and Macdonald (2003) in the United Kingdom. In all cases, for this study, core areas were completely exclusive as the American mink spent most time there and other minks avoided their neighbours’ core areas. Overlapping between resident and transient was higher than between resident minks. However, it is not considered as real overlap since transient minks do not stay long in another mink’s territory that is already established. All transients in our research were dispersing subadults looking for a territory.

4.2. Habitat selection inside the home range

The American mink do not spend the same amount of time along their home range, being most of the time in areas richer in dens and prey inside the home range (Gerell, 1970; Birks and Linn, 1982; Dunstone, 1993, Halliwell and Macdonald, 1996). These areas are the core areas and their selection depends on the factors that make them the more suitable to forage and breed. Site selection by small carnivores is the effect on three factors: protection against predators, proximity to preferred feeding areas and thermal isolation (Weber, 1989; Dunstone, 1993; Brainerd *et al.*, 1995; Lindström *et al.*, 1995; Halliwell and Macdonald, 1996; Genovesi and Boitani, 1997; Zalewski, 1997a).

In our study area, the selection of core areas was dependent on helophytic vegetation and the lack of human activity. The presence of helophytic vegetation can be interpreted as offering both refuge and prey. This vegetation is abundant in the area and tends to expand widely along the shoreline, forming areas of difficult access for humans and large animals, thus providing protection to minks (Palazón, 1998; Zabala *et al.*, 2001). Vegetation structure changes throughout the year as a consequence of the autumn floodings and the fast recovery of the vegetation in spring. Our minks did not select brambles as found in other studies (e.g. Zabala *et al.*, 2003) probably due to the easier access to helophytic vegetation. Furthermore, helophytic vegetation provides easier access to aquatic prey (mostly American crayfish). The importance helophytic vegetation for thermal isolation should be restricted to winter (Zalewski, 1997 a, b), and even then, the mild winters of Mediterranean areas might allow the minks to use it at low energetic cost. Presence of human activity either agriculture or industrial had a negative effect on minks. Agriculture in the area is represented by small private vegetable gardens were usually owners had also guard dogs, which can prey on minks.

4.3. Management implications

American mink in Catalonia represent a focus of population spread and a danger because of the considerable negative impacts that it can potentially have on native species through competition or predation (Palazón and Ruiz-Olmo, 1997; Palomo and Gisbert, 2002; Bonesi and Palazón, 2007). First, this population can spread and enter in contact with small and isolated populations of native prey that are actually vulnerable or endangered, for example the European crayfish, *Austropotamobius pallipes*, or the Iberian desman, *Galemys pyrenaicus*, (Palazón and Ruiz-Olmo, 1997; Palomo and Gisbert, 2002). Secondly, this population can spread through the river Ebro and enter in contact with the west side of the European mink population living in Northern Spain. The American mink population of Central Spain has already surrounded European mink populations in its Northern, Western and Southern part. Only the Eastern side is so far free from the American mink pressure (Palazón and Ruiz-Olmo, 1997; Bonesi and Palazón, 2007). Therefore, if the American mink population of Catalonia spreads it will close completely the European mink population, hindering its recovery.

We advice to design the trapping campaigns taking into account the home range sizes used by minks in this high density population and the variables pointing the preferred areas in order to be more successful in the control of mink populations. Following our results, most of the captures occur within core areas. Therefore, since we do not know where core areas are located beforehand we should locate traps every 200 m to maximize capturability. This roughly represents doubling the trapping effort (currently eradication campaigns set traps every 300 to 500 m). In this way we might increase the capture rate of resident animals, including breeding females (which normally show lower capture rates). Moreover, traps should be placed preferably near helophytic vegetation since it had a positive effect on space use. In its absence, traps should be located near any kind of vegetation providing coverage for mink, and far from human activity.

Acknowledegments

We thank Universitat de Barcelona, Generalitat de Catalunya and 02MNAT/8604 Life Project for funding this study. Y.M. is supported by a FPU Fellowship granted by the Spanish Ministerio de Ciencia y Tecnología (AP 2002-2653). We are grateful to Albert Roura for his collaboration in taking field data, and to the staff in the Centre de Recuperació d'Animals Torreferrussa for their help in manipulating animals and preparing the trapping material. Special thanks for her advices and ideas to Dr. Laura Bonesi, University of Trieste, Italy.

References

Barreto, G.R., Rushton, S.P., Strachan, R., Macdonald, D.W., 1998. The role of habitat and mink predation in determining the status and distribution of water voles in England. Anim. Conserv. 1, 129-137.

Birks, J.D.S., 1981. Home range and territorial behaviour of the feral mink (*Mustela vison* Schreber) in Devon. Ph.D. dissertation, Exeter University, Exeter, UK.

Birks, J.D.S., Linn, I.J., 1982. Studies in home range of feral mink, *Mustela vison*. Sym. Zool. Soc. Lond. 49, 231-257.

Birks, J.D.S., 1986. Mink. Antony Nelson, Oswestry, Shropshire, UK.

Bonesi, L., 1996. Spatial organization and feeding ecology of the American mink (*Mustela vison*) in a coastal habitat. M.Sc. thesis, University of Durham, Durham, UK.

Bonesi, L., Palazón, S. 2007. The American mink in Europe: Status, impacts, and control. Biol. Conserv. 34, 470-483.

Brainerd, S.M., Hellding, J.O., Lindström, E.R., Rolstad, E., Rolstad, J., Storch, I., 1995. Pine marten (*Martes martes*) selection of resting and denning sites in Scandinavian managed forests. Ann. Zool. Fenn. 32, 151-157.

Clode, D., Macdonald, D.W., 1995. Evidence for food competition between mink (*Mustela vison*) and otter (*Lutra lutra*) on Scottish islands. J. Zool. 237, 435-444.

Craik, J.C.A., 1999. Long-term effects on North American mink *Mustela vison* on seabirds in western Scotland. Bird Study. 44, 303-309.

Dunstone, N., Birks, J.D.S., 1983. Activity budget and habitat usage by coastal-living mink (*Mustela vison*). Act. Zool. Fenn. 174, 189-191.

Dunstone, N., 1993. The mink. T and A D Poyserd Ltd., London, UK.

Erlinge, S., 1972. Interspecific relations between otter (*Lutra lutra*) and mink (*Mustela vison*) in Sweden. Oikos. 23, 327-335.

Erlinge, S., Sandell, M., 1986. Seasonal changes in the social organisation of male stoats, *Mustela erminea*: an effect of shifts between two decisive resources. Oikos. 47, 57-62.

Ferreras, P., Macdonald, D. W., 1999. The impact of American mink *Mustela vison* on water birds in the upper Thames. Journal of Applied Ecoogy. 36. 701-708.

Garin, I., Zuberogoitia, I., Zabala, J., Aihartza, J., Clevenger, A., Rallo, A., 2002. Home range of European mink (*Mustela lutreola*) in Southwestern Europe. Acta Theriol. 47, 55-62.

Genovesi, P., Boitani, L., 1997. Day resting sites of stone marten. Hystrix. 9, 75-78.

Gerell, R., 1970. Home ranges and movements of the mink *Mustela vison* Schreber in southern Sweden. Oikos. 21, 160-173.

Gill, F.P, Wolf, L.L., 1975. Economics of feeding territoriality in the golden-winged. Sunbird Ecology. 56, 333-345

Halliwell, E.C., Macdonald, D.W., 1996. American mink *Mustela vison* in the upper Thames catchment: relationship with selected prey species and den availability. Biol. Conserv. 76, 51-56.

Harestad, A.S., Bunnel, F. L., 1979. Home range and body weight – a reavaluation. Ecology. 60, 389-402.

Ireland, M.C., 1988. The behaviour and ecology of the American mink (*Mustela vison* Schreber) in a coastal habitat. Ph.D. dissertation. Durham University, Durhan, UK.

Kenward, R., 1987. Wildlife radio tagging. Equipment, field techniques and data analysis. Academic Press, London.

Lindstedt, S.L., Miller, B.J., Buskirk, S.W., 1986. Home range, time and body size in mammals. Ecology. 67, 413-418.

Lindström, E.R., Brainerd, S.M., Helldin, J.O., Overskaug, K., 1995. Pine marten-red fox interactions: a case of intraguild predation? Ann. Zool. Fenn. 32, 123-130.

Loukmas, J.J., 1998. Criteria for quantifying mink (*Mustela vison*) habitat quality in great lakes basin. PhD dissertation, Southern Illinois University at Carbonade, USA.

Loukmas, J.J., Halbrook, R.S., 2001. A test for habitat suitability index model for riverine systems. Wildlife Soc. B. 29, 821-826.

Macdonald, R. A., Strachan, R., 1999. The mink and the watervole: analyses for conservation. Oxford: Wildlife Conservation Research Unit and Enviroment Agency.

Macdonald, D.W., Rushton, S., 2003. Modelling space use and dispersal of mammals in real landscapes: a tool for conservation. J. Biogeogr. 30, 607-620.

Maran, T., Robinson, P., 1996. European mink Captive Breeding and Husbandry Protocol. European mink Conservation and Breeding Committee. Tallin Zoo.

Maran, T., Macdonald, D.W., Kruuk, H., Sidorovich, N.V., Rozhnow, V.V., 1998. The continuing decline of the European mink *Mustela lutreola*: evidence for the intraguild aggression hypothesis. In: N. Dunstone and M. L. Gorman, editors. Behaviour and ecology of riparian mammals. Cambridge University Press, Cambridge, UK.

McNab, B.K., 1963. Bioenergetics and the determination of home range size. Am. Nat. 97, 133-140.

Melero, Y., Palazón, S., Bonesi, L., Gosàlbez, J. Feeding habits of three sympatric mammals in NE Spain: the American mink, the spotted genet, and the Eurasian otter. Submitted.

Nosdström, M., Korpimäki, E. 2004. Effects of island isolation and feral mink removal on bird communities on small islands in the Baltic Sea. J. Anim. Ecol. 73, 424-433.

Palazón, S., 1998. Distribución, morfología y ecología del visón europeo (*Mustela lutreola* Linnaeus, 1761) en la Península Ibérica. PhD thesis, Universitat de Barcelona.

Palazón, S., Ruiz-Olmo, J. 1995. Tracking of a female American mink (*Mustela vison*, Schreber, 1777) in NE Spain. Doñana Acta Vertebrata, 22 (1-2): 97-102.

Palazón, S., Ruiz-Olmo, J., 1997 El visón europeo (*Mustela lutreola*) y el visón americano (*Mustela vison*) en España. Serie Técnica ICONA, Madrid, Spain.

Palomo, J., Gisbert, J., 2002. Atlas de los Mamíferos terrestres de España. Organismo Autónomo de Parques Nacionales. DGCNA_MIMAM, Madrid, Spain.

Robitaille, J.F., Raymond, M., 1995. Spacing patterns of ermine, *Mustela erminea* L., in a Quebec agrosystem. Can. J. Zoolog. 73, 1827-1834.

Ruiz-Olmo, J., 2001. *Conservation Plan for the otter in Catalonia: biology and ecology*. Documents of Environment Notebooks Nº 6. Generalitat de Catalunya.

Sandell, M., 1989. The mating tactics and spacing patterns of solitary carnivores, in: Gittleman, J.L. (Ed.), Carnivore behaviour, ecology, and evolution. Chapman & Hall, London, pp. 164-182

Stevens,R.T., Ashwood, T.L., Sleeman, J.M., 1997. Fall-early winter home ranges, movements, and den use of male mink, *Mustela vison* in eastern Tennessee. Can. Field Nat. 111, 312-314

Strachan, R., Jefferies, D.J., 1993. The water vole *Arvicola terrestris* in Britain 1989-1990: its distribution and changing status. Vincent Wildlife Trust, London, UK.

Weber, D., 1989. The ecological significance of resting sites and the seasonal habitat change in polecats *(Mustela putorius*). J. Zool. 217, 629-638.

Zabala, J., Zuberogoitia, I., Garin, I., Aihartza, J.R., 2001. Small carnivore trappability: seasonal changes and mortality. A case study on European mink *Mustela lutreola* and spotted genet *Genetta genetta*. Small Carnivore Conservation. 25, 9-11.

Zabala, J., Zuberogoitia, Z., Garin, I., Aihartza, J.R., 2003. Landscape features in the habitat selection of European mink (*Mustela lutreola*) in south-western Europe. J. Zool. 260, 415-421.

Zalewski, A., 1997a. Factors affecting selection of resting site type by pine marten in primaveral deciduous forests (Bialowieza National Park, Poland). Acta Theriol. 42, 217-288.

Zalewski, A., 1997b. Patterns of resting site use by pine marten *Martes martes* in Bialowieza National Park (Poland). Acta Theriol. 42, 153-168.

Yamaguchi, N., Macdonald, D.W., 2003. The burden of co-occupancy: intraespecific resource competition and spacing patterns in American mink, *Mustela vison*. J. Mammal. 84, 1341-1355.

Yamaguchi, N., Rushton, S., Macdonald, D.W., 2003. Habitat preferences of feral American mink in the Upper Thames. J. Mammal. 84, 1356-1373.

Table 1. Size of the Home range, Core areas and home range overlap (%) of radiotracked individuals (2003, 2004 and 2005). Individual in rows overlap individual in blankets. Age refers to subadult (SA) or adult (A). Status refers to resident (r) or transient (t).

Figure 1. Linear home ranges and core areas of animals captured in 2003 (a, b, c); 2004 (d, e, f); and 2005 (g, h). Home range of transients is shown in continuous line for areas where they were radiolocated, and dichotomous line for areas where they were not radiolocated but through which they may pass in order to reach other areas.

Table 1.

Indiv.	Age	Status	Home range (km)	Core area (km)	Home range overlap (%)	Tracking period	№ tracked days	№ Locations
2003								
Male 1	SA	R	1.01	0.19	67 % (F1) 58 % (M3)	26/9-10/10	5	8
Male 2	A	R	1.01	0.19	-	24/9-4/12	33	66
Male 3	A	T	2.56	0.23	16 % (M1) 14 % (F1) 19 % (M4)	2/10-16/11	13	34
Male 4	A	R	0.71	0.36	68 % (M3)	13/11-29/12	22	34
Female 1	A	R	0.77	0.37	87 % (M1) 46 % (M3)	23/9-4/12	34	61
2004								
Male 5	A	R	0.44	0.13	-	19/10-2/11	11	15
Male 6	SA	T	2.61	0.31	14 % (M7) 16 % (M8) 16 % (M9) 19 % (M10) 5 % (F3) 8 % (M11)	2/12-15/2	31	99
Male 7	A	R	1.86	0.27	20 % (M6) 33 % (M11)	21/12-1/2	14	40
Male 8	SA	R	0.77	0.17	59 % (M10) 53 % (M6)	10/11-22/12	25	53
Male 9	A	R	0.71	0.15	57 % (M6) 9 % (M11)	10/11-3/12	15	28
Male 10	A	R	0.65	0.10	70 % (M8) 75 % (M6)	3/11-26/11	14	39
Male 11	A	T	1.60	0.11	39 % (M7) 4 % (M9) 12 % (F2) 13 % (M6)	14/12-19/1	23	48
Female 2	A	R	0.52	0.09	37 % (M11)	19/10-9/12	34	83
Female 3	SA	R	0.44	0.14	27% (M6)	1/12-6/3	47	436
2005								
Male 12	SA	R	0.68	0.24	-	18/10-4/11	13	33
Male 13	A	R	0.87	0.29	47 % (F5)	8/12-21/12	8	22
Female 4	A	R	0.53	0.19	-	31/10-25/11	19	32
Female 5	SA	R	0.42	0.15	100 %(M13)	23/11-14/12	11	24

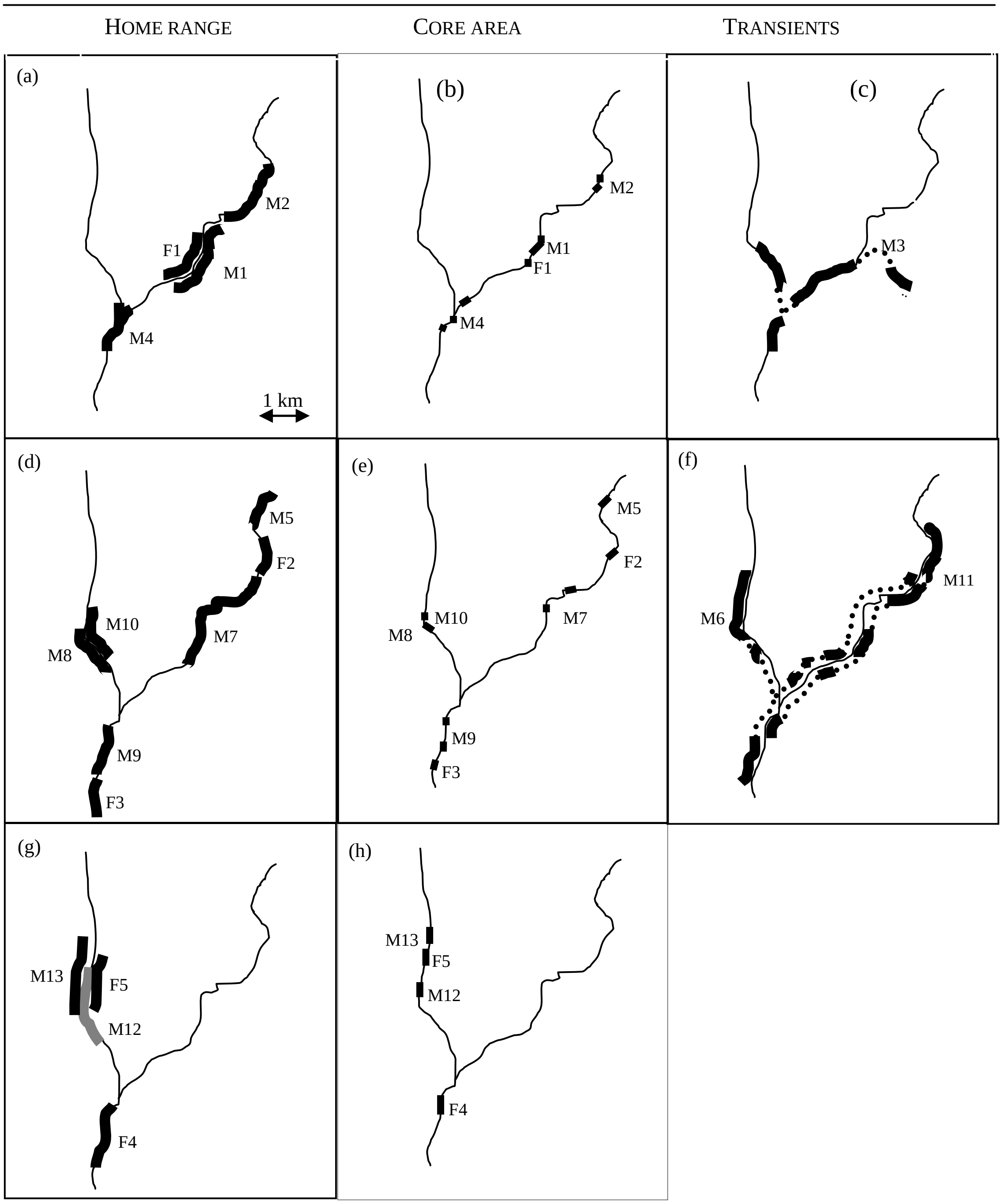

HOME RANGE
CORE AREA
TRANSIENTS
(a)
M2
F1
M1
M4
1 km
(b)
M2
M1
F1
M4
(c)
M3
(d)
M5
F2
M10
M7
M8
M9
F3
(e)
M5
F2
M10
M7
M8
M9
F3
(f)
M11
M6
(g)
M13
F5
M12
F4
(h)
M13
F5
M12
F4

Figure 1.

RESUMEN

El tamaño del territorio que ocupa y, en general, el patrón espacial del visón americano depende de factores como el tipo y la abundancia de vegetación, el agua, la contaminación, y la disponibilidad y la distribución de los recursos (Loukmas y Halbrook, 2001; Yamaguchi *et al.*, 2003). En el presente trabajo se estudia el patrón espacial (tamaño del área núcleo y vital de los individuos y sus posibles solapamientos), la selección de hábitat intra-territorial y los posibles factores que afectan a ambos.

El estudio se realizó a lo largo de 6 km de curso fluvial del río Llobregat y a lo largo de 5 km de su afluente la riera Gavarresa. Se llevó a cabo una sesión de trampeo anual durante los meses de octubre a diciembre de 2003, 2004 y 2005 con 588 trampas noche por sesión. Los ejemplares capturados fueron anestesiados, manipulados y liberados tras su recuperación de los efectos de la anestesia. Se marcó a cada uno de los animales con un transponder magnético (Trovan Ltd., Madrid, España) y a algunos de ellos se les colocaron collares radiotransmisores de frecuencia entre 150 y 151 MHz (BioTrack, Ltd., Wareham, Dorset, UK y Tinyloc Ltd., Mataró, España).

Las radiolocalizaciones de los ejemplares se tomaron directamente cada hora entre el amanecer y el atardecer sin triangulación, dado que los movimientos del visón siguen el curso fluvial (Gerell, 1970; Birks y Linn, 1982; Ireland, 1990; Bonesi, 1996). Adicionalmente, se realizaron doce seguimientos intensivos de 24h con localizaciones cada 30min. En el análisis de los datos, el área vital, el área núcleo y el solapamiento se han calculado como longitud de río utilizado por los individuos empleando el programa ArcView GIS 3.2 (Enviromental System Research Institute, Inc., USA). Se han analizado también posibles factores que podrían afectar al patrón

espacial de los residentes utilizando un modelo lineal general mixto (GLMM). Las variables observadas han sido: sexo, peso, edad, río, y la variable formada por la interacción entre el número de días de radioseguimiento y el número de radiolocalizaciones. Finalmente, se ha analizado la selección de hábitat mediante un GLMM, observando la relación entre porcentaje de radiolocalizaciones *versus* los siguientes factores: abundancia de vegetación helofitica, abundancia de vegetación arbustiva, sección del río y presencia de actividad humana.

Se capturaron un total de 50 visones americanos, de los cuales se han obtenido datos de 18 (5 en 2003, 9 en 2004 y 4 en 2005) (Tabla 2). El área vital resultante es de 0,82 ± 0,17 km para los machos adultos residentes (n = 7), de 0,61 ± 0,14 km para las hembras adultas residentes (n = 3), de 0,82 ± 0,17 km para los machos subadultos residentes (n = 3), y de 0,43 ± 0,01 km para las hembras subadultas residentes (n = 2). En el caso del área núcleo los resultados son de 0,21 ± 0,09 km para los machos adultos, de 0,21 ± 0,14 km para las hembras adultas, de 0,20 ± 0,04 km para los machos subadultos, y de 0,43 ± 0,01 km para las hembras subadultas (Tabla 1; Figs. 1 y 2). El solapamiento entre áreas vitales de los residentes resulta ser bajo (Tablas 2, 3 y 4; Fig. 1 (a), (c), y (e)); en ningún caso se detecta solapamiento entre las áreas núcleo. Los factores peso y río se manifiestan como significativos para el tamaño del área vital. Ningún factor es significativo en el caso del área núcleo. El porcentaje de capturas resulta mayor dentro de las áreas núcleos que fuera ($\chi^2 = 5.71$, df = 1, $p < 0.025$). En relación a las variables de hábitat, la abundancia de vegetación helofítica presenta un efecto positivo en el porcentaje de radiolocalizaciones por sección (F = 3.45, df = 5, P = 0.007), mientras que la presencia de actividad humana tiene un efecto negativo (F = 3.18, df = 2, P = 0.047). La abundancia de vegetación helofítica presenta un efecto, en este caso, casi significativo en el caso del porcentaje de capturas (F = 0.87, df = 5, P = 0.53).

El menor tamaño territorial de la población estudiada en comparación con otras poblaciones implica una eleva capacidad de carga de la zona.

Los tamaños territoriales de los individuos del área de estudio resultan menores a los esperados según otros estudios (ej. Birks y Linn, 1982; Yamaguchi y Macdonald, 2003; Gerell, 1970; Palazón *et al.*, 1995; Stevens *et al.*, 1997). A pesar de esto, los individuos estudiados presentan una buena condición física (Melero *et al.*, aceptado) lo cual nos indica que el área presenta una elevada capacidad de carga suficiente para proporcionar a los individuos los recursos necesarios incluso en territorios menores a los esperados para la especie. De hecho, el efecto significativo del peso pone de manifiesto la importancia de la condición física de los ejemplares en el mantenimiento del territorio (Yamaguchi y Macdonald, 2003). El río Llobregat, el mayor de los dos, presenta territorios mayores a los encontrados en su afluente la riera Gavarresa. Este resultado se explica por el hecho de que el río Llobregat, por su tamaño, presenta mayor disponibilidad de presas y por tanto mayor capacidad de carga permitiendo que los territorios sean menores. En relación a la selección de hábitat, la vegetación helofítica ejerce un efecto positivo sobre las poblaciones de visón americano, dado que proporciona tanto refugio como alimento (Arrambari *et al.*, 1997; Palazón, 1998; Zabala *et al.*, 2001), mientras que la presencia de actividad humana representa un peligro potencial para el visón, por lo que es lógico considerar que presenta un efecto negativo en el mantenimiento de las poblaciones.

Ante los resultados obtenidos se considera que la metodología de trampeo del visón americano en el área de estudio y áreas con características similares debe seguir las siguientes recomendaciones: las trampas se deben colocar a una distancia entre ellas de aproximadamente 200 m en base al tamaño medio de las áreas núcleo, y preferentemente en puntos con presencia de vegetación helofítica y ausencia de actividad humana.

Patterns of activity in an invading Mediterranean population of American mink, *Mustela vison**

Yolanda MELERO, Santiago PALAZÓN[1,2], Eloy REVILLA [3], Joana MARTELO [4] and Joaquim GOSÀLBEZ[1].

Abstract

Patterns of circadian activity and the factors affecting it were studied in an invading Mediterranean population of American mink, *Mustela vison*. We distinguished between local activity, defined by active behavior without spatial displacement, locomotion activity as active locomotion behavior while foraging or travelling, and inactivity as resting behaviour. The effect of sex, age, daylight (diurnal and nocturnal), month, river flow and average rainfall per day was also studied on 8 males and 3 females. Male minks showed more locomotion activity than females, while subadults had more locomotion activity than adults. Average rainfall per day had also a negative effect on locomotion. By contrast, daylight had effect on neither total activity nor locomotion activity. Studied minks spent most of their time inactive in-den. We also studied differences in the results due to type of transmitters used. Commonly, transmitters without local activity sensor have been broadly used for activity behaviour studies. We demonstrated the subjectivity underlying in detecting the circadian activity based on them. Differences in the active and inactive behaviour of studied minks were found depending on type of transmitter used. Therefore, we encourage using transmitters with local activity sensor.

Department of Animal Biology (Vertebrates), University of Barcelona, Av. Diagonal, 645, 08028, Barcelona, Spain, e-mail: melero@ub.edu (YM), jgosalbez@ub.edu (JG); Department of Environment and Housing, Generalitat de Catalunya, Doctor Roux, 80, 08017, Barcelona, Spain, santiago.palazon@gencat.net (SP); Department of Applied Biology, Estación Biológica de Doñana, Spanish Council for Scientific Research-CSIC, Avenida Maria Luisa, s/n. Pabellón del Perú. 41013, Sevilla, Spain, revilla@ebd.csic.es (ER); Rua São Joãa de Deus, 1, 7600-033, Aljustrel, Portugal, joanamartelo@gmail.com (JM).

Key words: Local activity sensor, Locomotion, Local activity, Inactivity, *Mustela vison*, Postbreeding season.

Running page headline: Activity of an American mink population.

---

* Acta Theriologica, under review.

Introduction

The circadian activity patterns of most mustelid species correlate with photoperiod length (Hainard 1961, Ewer 1968), which seems to be the factor that most influences small Carnivores' activity pattern (Ashoff 1966, Saint-Girons 1966). Other extrinsic and intrinsic factors affecting this pattern are temperature (Ewer 1968, Richardson *et al.* 1987, Buskirk *et al.* 1988, Jedrzejewski *et al.* 2000, Zalewski 2000), predator activity (Powell 1973, Richardson *et al.* 1987), prey abundance and activity (Gerell 1969, Zielinski *et al.* 1983), sex, age or body mass (Zalewski 2000).

The American mink, *Mustela vison* Schreber, is a riparian mustelid commonly showing a nocturnal activity (Gerell 1969, Birks & Linn 1982) although Niemimaa (1995) could not find a clear nocturnal activity in an introduced population of the Finnish outer archipelago. Overall mink spend more time inactive than active per day (Dunstone & Birks 1983, Ireland 1990) being most of the time inside their dens (Dunstone & Birks 1983). Since the introduction of this species in Europe, Russia and South America for fur-farming in the early 20th century, feral populations had established and spread following deliberate release or accidental escapes (Vidal-Figueroa & Delibes 1987, Smal 1988, Linn & Birks 1989, Dunstone 1993). Its spreading poses a serious ecological problem in Europe, Asia and South America, while some native populations are suffering a decline in North America (Osowski *et al.* 1995). For both reasons governments are financing mink control programmes and the knowledge of its ecology and specifically its activity patterns has increased in the last years. In Spain a control programme is running since 2001 to protect the remaining populations of European mink, *Mustela lutreola*. Information on the patterns of activity in the affected areas will allow us to improve the efficiency of trapping efforts and to know which prey species can be most affected by mink predation or competition.

In this paper we describe the patterns of activity in a mink population established in Catalonia (Northeast of the Iberian Peninsula), one of the few Mediterranean areas affected by its invasion. Mink behaviour can differ from other areas due to contrasting environmental conditions, such as Mediterraneity. Mediterranean environments present high variability in seasonal patterns with strong autumn rainfalls and subsequent floodings, and extremely dry and hot summers with temporal rivers (di Castri & Mooney 1973). This may affect factors as abundance of dens or prey availability. However, studies on invading Mediterranean mink populations are scarce. Our main aim is to describe the daily activity rhythm and to evaluate possible differences between total activity (both local movement and locomotion versus inactivity) and locomotion activity (versus local activity) by analysing how sex, age, daylight, month, river flow and average rainfall affect them.

As second aim, we tested possible differences in detecting activity due to transmitters with and without local activity sensor. Most of the studies have used transmitters without local activity sensor (for example Gerell 1969, Niemimma 1995, Birks and Linn 1982, Ireland 1990). These transmitters only allow detecting variations in signal strength. Therefore, only locomotion activity can be detected. Animals with these transmitters are classified as either active with locomotion or inactive according to the level of variation in strength of the radio signal (Kenward 1987). Meanwhile, transmitters with local activity sensor allow detecting differences in signal pulse rate and differences in signal strength. Differences in pulse rate inform if animals have an active or an inactive behaviour. Active behaviour can imply spatial displacement (locomotion) or local movement without locomotion. Thus, animals with transmitters with local activity sensor are classified as either active with locomotion, active without locomotion (local activity), or inactive (resting) depending on changes in the signal pulse rate and the signal strength. A slow signal implies inactive behaviour. A fast signal speed with constant signal strength implies local movement, whereas a fast signal speed with changes in signal strength implies locomotion (Kenward 1987). We wanted to test if the use of sensor activity on transmitters differs in their results with the non use of sensor activity which is, in fact, the most commonly used.

Study area

The study was conducted in Bages region (1º 53'N, 41º 49' E) in the centre-eastern part of Catalonia (Spain). The area included 6 km of the Llobregat River, 5 km of its tributary Gavarresa, and their banks. The average annual rainfall is about 490 mm and the altitude ranges between 160 m and 350 m. The riparian vegetation is dominated by *Arundo donax*, *Typha latifolia*, *Phragmites communis*, *Juncus* sp., *Rubus ulmifolius*, *Populus alba* and *Salix* spp. This typical Mediterranean area is characterised by a strong summer drought and torrential autumn rainfalls whose subsequent floodings reduce vegetation cover yearly.

Materials and methods

Mink trapping and radiotracking

One trapping session was conducted annually with 588 trap-nights per session in 2003, 2004 and 2005. The sessions were set each year between October and December in both rivers. Animals were live-trapped in single cage traps (15 x 15 x 60 cm) located on both river sides with a separation of 300-400m between them and checked daily. After immobilization with 0.15 ml of ketamine (Imalgéne, Rhone Merieux, Lyon, France) and 0.03 ml of medetomidine (Domtor, Pfizer SA, Madrid, Spain), manipulated animals were released in the capture area once fully recovered. Trapping was made during the post breeding season (September to February) when there are no juvenile minks (all animals older than 5 months). Animals were classified by their sex and age (subadults 5-8 months old; and adults >8 months old) based on a combination of teeth condition and weight (Maran & Robinson 1996).

The captured animals were marked with a transponder (Trovan Ltd., Madrid, Spain) in order to distinguish between new captures and recaptures. Some of them were also marked with waterproof radiotransmitter collar necks (frequency 150 and 151 MHz, BioTrack, Ltd., Wareham, Dorset, UK and Tinyloc Ltd., Mataró, Spain). Radiocollars weighted approximately 15 g, < 3 % of the lightest adult mink captured during the study (510 g). All procedures were approved by the Scientific Ethical Committee of the Department of Environment and Housing of the Catalonian Government (Spain).

A TR4 (Telonics Ltd., Mesa, Arizona, USA) receiver was used connected to multidirectional or bidirectional antennas. Radiolocations were recorded by homing to the animals (U.T.M. positions, using a Garmin GPS, Romsey, Hampshire, UK) without triangulation as mink movements follow the river course (Gerell 1970, Birks & Linn 1982, Ireland 1988, Bonesi 1996). Radiotracking was made daily every hour unless it took longer to find the animal. Additionally, 24 h radiotracking periods were made taking a location every 30 min. Hour time was set as Universal Time Coordinates (UTC).

Two types of transmitters were used. Type 1 transmitters had a sensor of local activity. Then, animals were classified as active with local movement, active with locomotion or inactive using the combination of signal speed and variation in signal strength. A total of 903 radiolocations using Type 1 transmitters were gathered from

October until collars stopped working, being the latest locations in February (Table 1).

Type 2 transmitters had no sensor of local activity. Animals were classified as active or inactive based on the signal strength. A total of 720 radiolocations using Type 2 transmitters were gathered from October until collars stopped working, being the latest locations in March (Table 1).

Sensor analysis

Differences between both types of transmitters were tested to assure that joining data obtained from each of them was correct. All radiolocation data were divided as Type 1 and Type 2 transmitter data. Data was pooled as activity with locomotion (n = 345) or without locomotion (inactive radiolocations plus active radiolocations without spatial displacement, n = 1278) for both types of transmitters. Then locomotion activity *versus* locomotion inactivity depending on the type of transmitter was analysed. Possible differences were tested using a general linear mixed model (GLMM), setting type of transmitter as fixed effect. Sex, age, daylight (diurnal and nocturnal), month, river flow and average rainfall per day were also set as fixed effects to control for any potential effect due to these factors. Individual and river (Llobregat or Gavarresa) were set as random effects. Thereafter and based on the results obtained; only data from Type 1 transmitters were used in the study.

Activity analysis

Using the data from the Type 1 transmitter, we distinguished between local activity, locomotion activity and inactivity. Local activity was defined as active behavior without displacement, locomotion activity as active locomotion behavior while foraging or travelling (active behaviour with displacement), and inactivity as resting. Mink activity was studied using all radiolocations and continuous 24h tracking sessions and pooling them in 1h periods. First the daily activity was studied by pooling all the data, as percentage of local activity, percentage of locomotion activity and percentage of inactivity. Second, the daily activity rhythm was defined as percentage of local, locomotion activity or inactivity per hour. Finally, diurnal and nocturnal activity was defined as percentage of local, locomotion activity and inactivity during daylight and during night. Diurnal time was set between dawn and dusk for each day and nocturnal between dusk and dawn.

Total activity (all local and locomotion activity radiolocations pooled together, n = 376) *versus* inactivity (inactivity radiolocations, n = 527) was studied, analysing the influence of sex, age, daylight (diurnal and nocturnal), month, river flow and average rainfall per day using GLMM. Factors were set as fixed effects. Individual and river (Llobregat or Gavarresa) were set as random effects. We included the individual as a random effect to avoid pseudoreplication problems. Finally, we also studied locomotion activity (n = 187) *versus* local activity (n = 189).

The influence on locomotion activity of sex, age, daylight, month, river flow and average rainfall was analysed using GLMM under the same conditions as before.

River flow (m^3/s) is measured as daily mean flow for both rivers Llobregat and Gavarresa in the study area. Rainfall (mm) is measured as daily mean rainfall in the study area.

Results

A total of 27 minks were trapped and marked with radiocollars (17 with Type 1 and 10 with Type 2 transmitters, respectively). Overall, we obtained data from 19 minks (11 with Type 1 and 8 with Type 2) (Table 1). The rest of them took off the collar, or were lost due to collar failure.

Sensor analysis

There were found significant differences between both types of transmitters, sex, age and rainfall (Table 2 and Fig. 1a). Hereafter, only the data provided by the transmitters with local activity sensor was used (Type 1). Otherwise, locomotion would be severely underestimated since probability of locomotion detection is much higher for Type 1 transmitters (Fig. 1a).

Activity analysis

Following the data obtained with Type 1 transmitters of 8 males and 3 females, animals tracked spent almost half of their time active with a total of 27.6 % of local activity and 13.9 % of locomotion activity (Fig. 2). During diurnal time, minks in the study area presented 29.4 % of local activity and 13.3 % of locomotion activity. Whereas, nocturnal activity was represented by 15.4 % of local activity and 20.3 % of locomotion activity (Fig. 2 and 3).

There was no significant effect of any factor on total activity (Table 2 and Fig. 2). The GLMM for locomotion *versus* local activity showed a positive effect of sex and of age (Table 2 and Fig.1b and 1c) and a negative effect of average rainfall (Table 2). Daylight was not a significant factor for locomotion activity, although minks showed slightly more locomotion activity during the night (Table 2 and Fig. 1d and 2).

Discussion

Type of transmitter

By using Type 2 transmitters we can detect only active behaviour involving spatial movement due to travel or foraging. Therefore, in-den or local movement behaviour can be understood as inactive behaviour as animals do not move spatially. However, Type 1 transmitters show both local movement behaviour and locomotion behaviour. Moreover, important differences in total activity depending on sensor Type were found. For this reason, only data from Type 1 transmitters was used. Other significant factors were sex, age and average rainfall per day, which was the same result using only data from Type 1. This supports that we are not loosing information while removing Type 2 data from the analysis but we are assuring a better detection of active radiolocations.

As pointed before, Type 2 transmitters can underestimate total activity (both local and locomotion). In fact, our results showed that minks were active (both local and locomotion activity) a total of 41.5 % of the time, and presented locomotion activity 13.9 % of the time; meanwhile other studies have found a lower percentage of total activity. Gerell (1969) found an overage of 29 % of active behaviour in 9 minks. Failure in detecting signal strength may explain these differences but it shows the subjectivity underlying in detecting activity based on changes on signal strength. Therefore, we strongly recommend using Type 1 transmitters to avoid errors in detecting active behaviour.

Mink activity

Based on the results, American minks in the study area, and during the study period (October-February), use little time in foraging and travelling, and spend most of the time inside or close to their dens active or inactive what is in concordance with Dunstone & Birks (1983) in the United Kingdom.

Daily rhythm did not show any general pattern. There was a similar percentage of active radiolocations during daylight and night. Locomotion activity only showed a slightly higher percentage of active radiolocations at night. Again that supports that American minks spend little time foraging or travelling.

In general, mustelids either native or invasive have been reported as more nocturnal than our population (Ireland 1990, Dunstone 1993, Palazón & Ruiz-Olmo 1997, Garin *et al.* 2002a, Garin *et al.* 2002b). However, the pattern of activity of carnivores is known to coincide with that of their most common preys (Laundré & Keller 1981, Zielinski *et al.* 1983, Ferguson *et al.* 1988) and so is American mink's (Gerell 1969, Bonesi *et al.* 2000). Scats collected during autumn and winter in the study area show that fish, small mammals, birds and specially crayfish are the main food sources for both sexes (Melero *et al.*, submitted). Only small mammals are nocturnal, so they can only be hunted at night. Thus, American minks can hunt at both diurnal and nocturnal periods. Hunting at night should imply a higher foraging success because all major prey types are present. Fish and crayfish can be hunted either in daylight or at nigh but they are easier trapped during daylight when visibility is better. This would explain why American mink in the studied area is less nocturnal than in other areas.

The biological factors sex and age affected only the locomotion activity of the studied minks. Once again this correlates with most mustelids locomotion activity pattern as males tend to be more active than females and subadults use to be also more active than adults (Ireland 1990, Dunstone 1993, Palazón & Ruiz-Olmo 1997, Garin *et al.* 2002a, Garin *et al.* 2002b, Revilla & Palomares 2002).

River flow did not affect either total activity or locomotion activity, as it probably does not affect foraging or displacement. Minks are good swimmers and changes in flow are not big enough to imply a decrease in hunting efficacy. However, average rainfall per day affected locomotion activity. Although this factor is not important for other populations, the Mediterranean population is negatively affected by rain. Mediterranean areas have irregular rain patterns with infrequent but strong autumn storms that may disturb individual behaviour.

Acknowledgements

The Universitat de Barcelona, the Generalitat de Catalunya and Life Project 02MNAT(E/864) funded this study. Y.M. was supported by a FPU Fellowship granted by the Spanish “Ministerio de Ciencia y Tecnología” (AP 2002-2653). ER was supported by a Ramón y Cajal contract (RyC2003). The Catalonian “Estació Meteorològica de Catalunya” provided the official data of flow and rainfall. We are also grateful to Albert Roura, the staff of the “Centre de Recuperació d’Animals Torreferrusa” and of the “Servei de Protecció de Fauna”. We are especially grateful to José Domingo Rodriguez-Teijeiro for his review and advice.

References

Ashoff J. 1966. Circadian activity within two peaks. Ecology 47 657-662.

Birks J. D. S. and Linn I. J. 1982. Studies of the home range of the feral mink (*Mustela vison*). Symposium of the Zoological Society of London 49 231-251.

Bonesi L. 1996. Spatial organization and feeding ecology of the American mink (*Mustela vison*) in a coastal habitat. M.Sc. thesis, University of Durham, Durham, United Kingdom.

Bonesi L., Dunstone N. and O'Conell M. 2000. Winter selection of habitats within interdital foranging areas by mink. Journal of Zoology 250: 419-424.

Buskirk S. W., Harlow H. J. and Forrest S.C. 1988. Temperature regulation in American marten (*Martes Americana*) in winter. National Geographic Research 4:208-218.

Di Castri F. and Mooney H. A. 1973 (eds.). Mediterranean-type ecosystems: origin and structure. Ecological studies: analysis and synthesis. Vol. 7. Heidelberg, Germany, Springer.

Dunstone N. and Birks J. D. S. 1983. Activity budget and habitat usage by coastal-living mink (*Mustela vison*). Acta Zoologica Fennici 174: 189-191.

Dunstone N. 1993. The mink. T. and A. D. Poyserd Ltd., London, United Kingdom.

Ewer R. F. 1968. Ethology of Mammals. Logos Press, London, United Kingdom.

Ferguson J. W. H., Galpin J. S. and De Wet M. J. 1988: Factors affecting the activity pattern of black-backed jackals. Journal of Zoology 214: 55-69.

Garin I., Zuberogoitia I., Zabala J., Aihartza J., Clevenger A. and Rallo A. 2002a. Home range of European mink (*Mustela lutreola*) in Southwestern Europe. Acta Theriologica 47: 55-62.

Garin I., Aihartza J., Zuberogoitia I. and Zabala J. 2002b. Activity pattern of European mink (*Mustela lutreola*) in Southwestern Europe. Zeitschrift für Jagdwissenschaft 48:102-106.

Gerell R. 1969. Activity patterns of the mink *Mustela vison* Schreber in southern Sweden. Oikos 20: 451-460.

Gerell R. 1970. Home ranges and movement of the mink *Mustela vison* Schreber in southern Sweden. Oikos 21: 160-173.

Hainard R. 1961. Mamifères Sauvages d'Europe. Delachaux and Nièstlé, Neuchâtel, Switzerland.

Ireland M.C. 1988. The behaviour and ecology the American mink (*Mustela vison* Schreber) in a coastal habitat. Ph.D. dissertation, Durham University, Durham, United Kingdom.

Ireland M.C. 1990. The behaviour and ecology of the American mink (*Mustela vison* Schreber) in a coastal habitat. PhD. Thesis. Durham University, Durham, United Kingdom.

Jedrzejewski W., Jedrzejewska B., Zub K. and Nowakowski W. K. 2000. Activity pattern of radio-tracked weasels *Mustela nivalis* in Bialowieza National Park (E Poland). Annales Zoologici Fennici 37:161-168.

Kenward R. 1987. Wildlife radio tagging. Equipment, field techniques and data analisys. London Academic Press.

Laundré J. W. and Keller B. L. 1981. Home range use by coyotes in Idaho. Animal Behaviour 29:449-461.

Linn I. and Birks J. D. S. 1989. Mink (Mammalia; Carnivora; Mustelidae): correction of a widely quoted error. Mammalian Review 19: 175-179.

Maran T. and Robinson P. 1996. European mink Captive Breeding and Husbandry Protocol. European mink Conservation and Breeding Committee. Tallinn Zoo, Tallinn, Estonia.

Melero, Y., Palazón, S., Bonesi, L. and Gosàlbez, J. 2007. Feeding habits of three sympatric mammals in NE Spain: the American mink, the spotted genet, and the Eurasian otter. Acta Theriologica, submitted.

Niemimaa J. 1995. Activity patterns and home range of the American mink *Mustela vison* in the Finnish outer archipelago. Annales Zoologici Fennici 32:117-121.

Osowski S.L., Brewer L.W., Baker O.E. and Cobb G. P. 1995. The decline of mink in Georgia, North Carolina and South Carolina: the role of contaminants. Archives of Environmental Contamination and Toxicology (Historical Archives) 29:418-423.

Palazón S. and Ruiz-Olmo J. 1997. El visón europeo (*Mustela lutreola*) y el visón americano (*Mustela vison*) en España. Ed. Ministerio de Medio Ambiente. Madrid.

Powell R. A. 1973. A model for raptor predation on weasels. Journal of Mammalogy 54:259-260.

Revilla E. and Palomares F. 2002. Spatial organization, group living and ecological correlates in low-density populations of Eurasian badgers, *Meles meles*. Journal of Animal Ecology. 71: 497-512.

Richardson L., Clark T. W., Forrest S. C. and Campbell T. M. 1987. Winter ecology of the black-footed ferret at Meeteetee, Wyoming. American Midland Naturalist 117:225-239.

Saint-Girons M. C. 1966. Le rythme circadian d'activité chez les mammifères holarctiques. Mémoires du Muséum National d'Histoire Naturelle, Zoologie 40: 101-187. Paris, France.

Smal C. M. 1988. The American mink *Mustela vison* in Ireland. Mammal Review 18:201-208.

Vidal-Figueroa T. and Delibes M. 1987. Primeros datos sobre el visón americano (*Mustela vison*) en el Suroeste de Galicia y Noroeste de Portugal. Ecología 1: 145-152.

Zalewski A. 2000. Factors affecting the duration of activity by pine martens (*Martes martes*) in the Bialowieza National Park, Poland. Journal of Zoology 251: 439-447.

Zielinski W. J., Spencer W. D. and Barret R. H. 1983. Relationship between food habits and activity pattern of pine marten. Journal of Mammalogy 64:387-396.

Table 1. Data of captured individuals during the trapping sessions (2003, 2004 and 2005). Age refers to subadult (SA) or adult (A). Transmitter type refers to transmitter with local activity sensor (1) or without local activity sensor (2).

Individual	Age	Transmitter Type	Tracking period	Nº Radiolocations
2003				
Male 1	SA	2	26/9-10/10	14
Male 2	A	1	24/9-4/12	200
Male 3	A	1	2/10-16/11	118
Male 4	A	1	13/11-29/12	34
Female 1	A	1	23/9-4/12	190
Female 2	SA	1	7/11-28/11	20
2004				
Male 5	A	1	19/10-2/11	28
Male 6	SA	1	2/12-15/2	99
Male 7	A	1	21/12-1/2	40
Male 8	SA	1	10/11-22/12	53
Male 9	A	1	10/11-3/12	38
Male 10	A	2	3/11-26/11	39
Male 11	A	2	14/12-19/1	48
Female 3	A	1	19/10-9/12	83
Female 4	SA	2	1/12-6/3	436
2005				
Male 12	SA	2	18/10-4/11	33
Male 13	A	2	8/12-21/12	22
Female 5	A	2	31/10-25/11	90
Female 6	SA	2	23/11-14/12	38

Table 2. Results of the GLMM for the analyses of sensor (Type 1 *vs* Type 2), total activity (active *vs* inactive) and locomotion activity (locomotion *vs* local activity). Individual and river were introduced as random effects in the models. d.f.: degrees of freedom. Significant factors are in cursive.

Model-fixed effect	F	d.f.	P
Sensor analysis			
Type of transmitter	6.14	1	0.013
Sex	57.19	1	<0.0001
Age	12.82	1	0.003
Daylight	1.29	1	0.27
Month	2.45	1	0.10
Flow	0.43	1	0.51
Rainfall	30.39	1	<0.0001
Total activity			
Sex	2.85	1	0.14
Age	2.48	1	0.16
Daylight	4.36	1	0.07
Month	1.63	3	0.28
Flow	0.08	1	0.78
Rainfall	1.70	1	0.19
Locomotion activity			
Sex	9.37	1	0.022
Age	7.23	1	0.036
Daylight	4.75	1	0.08
Month	3.01	3	0.16
Flow	0.10	1	0.75
Rainfall	5.82	1	0.016

Fig. 1. Probability of (a) Locomotion activity according to transmitters type, (b) Locomotion and local activity according to sex, (c) Locomotion and local activity according to age, and (d) Locomotion and local activity according to daylight. Values are given as mean and their standard error calculated from the GLMM all else being equal.

Fig. 2. Daily local activity and daily locomotion activity of American minks. Values are given as percentage of activity locations per hour.

Fig. 3. Diurnal and nocturnal inactivity, local activity and locomotion activity. Values are given as active and inactive percentage of radiolocations.

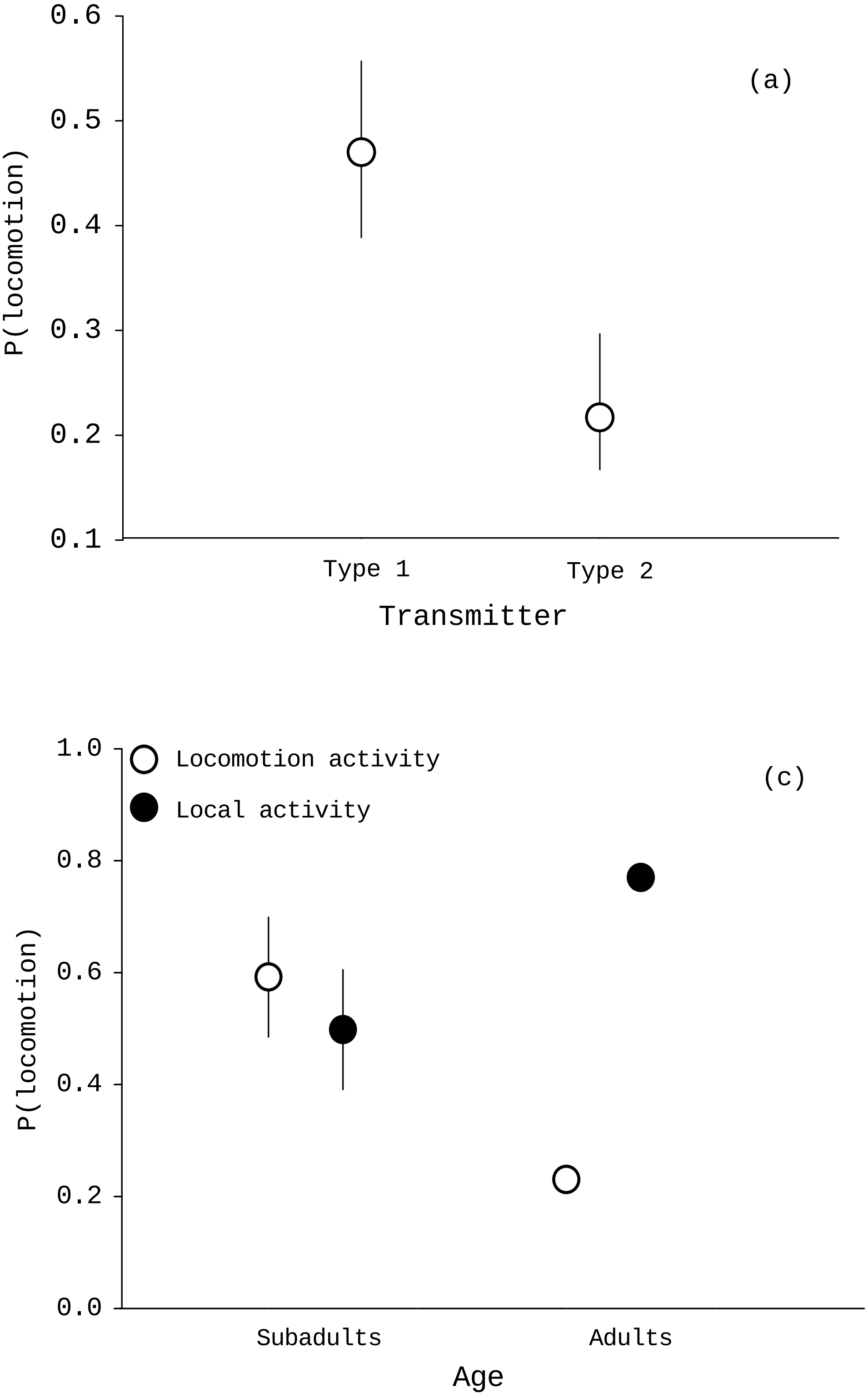

(a)
0.6
0.5
0.4
0.3
0.2
0.1
P(locomotion)
Type 1
Type 2
Transmitter
(c)
1.0
0.8
0.6
0.4
0.2
0.0
○ Locomotion activity
● Local activity
P(locomotion)
Subadults
Adults
Age

Fig. 1.

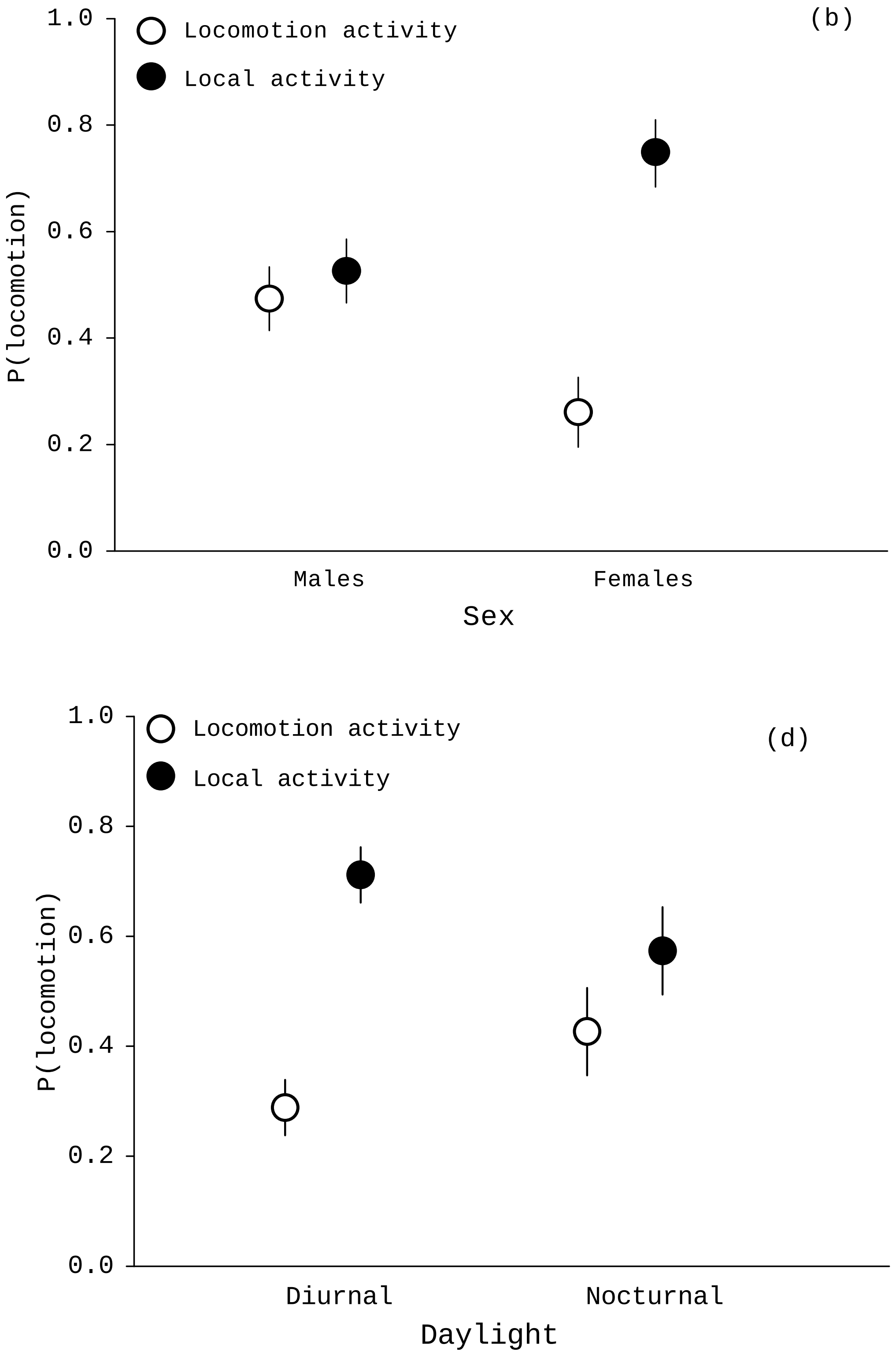

1.0
0.8
0.6
0.4
0.2
0.0
P(locomotion)
○ Locomotion activity
● Local activity
(b)
Males
Females
Sex
1.0
0.8
0.6
0.4
0.2
0.0
P(locomotion)
○ Locomotion activity
● Local activity
(d)
Diurnal
Nocturnal
Daylight

Fig. 1.

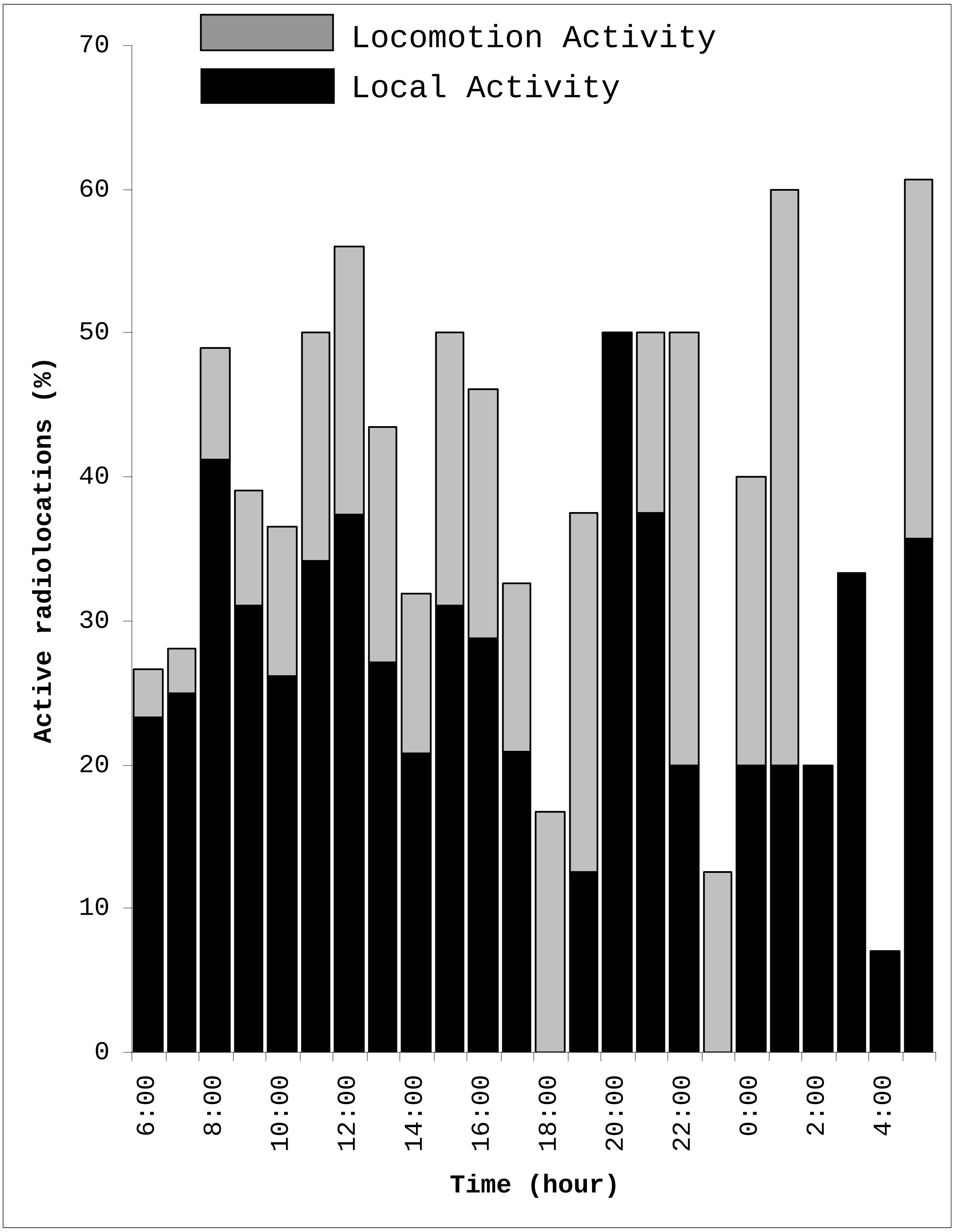

Locomotion Activity
Local Activity
Active radiolocations (%)
0
10
20
30
40
50
60
70
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
2:00
4:00
Time (hour)

Fig. 2.

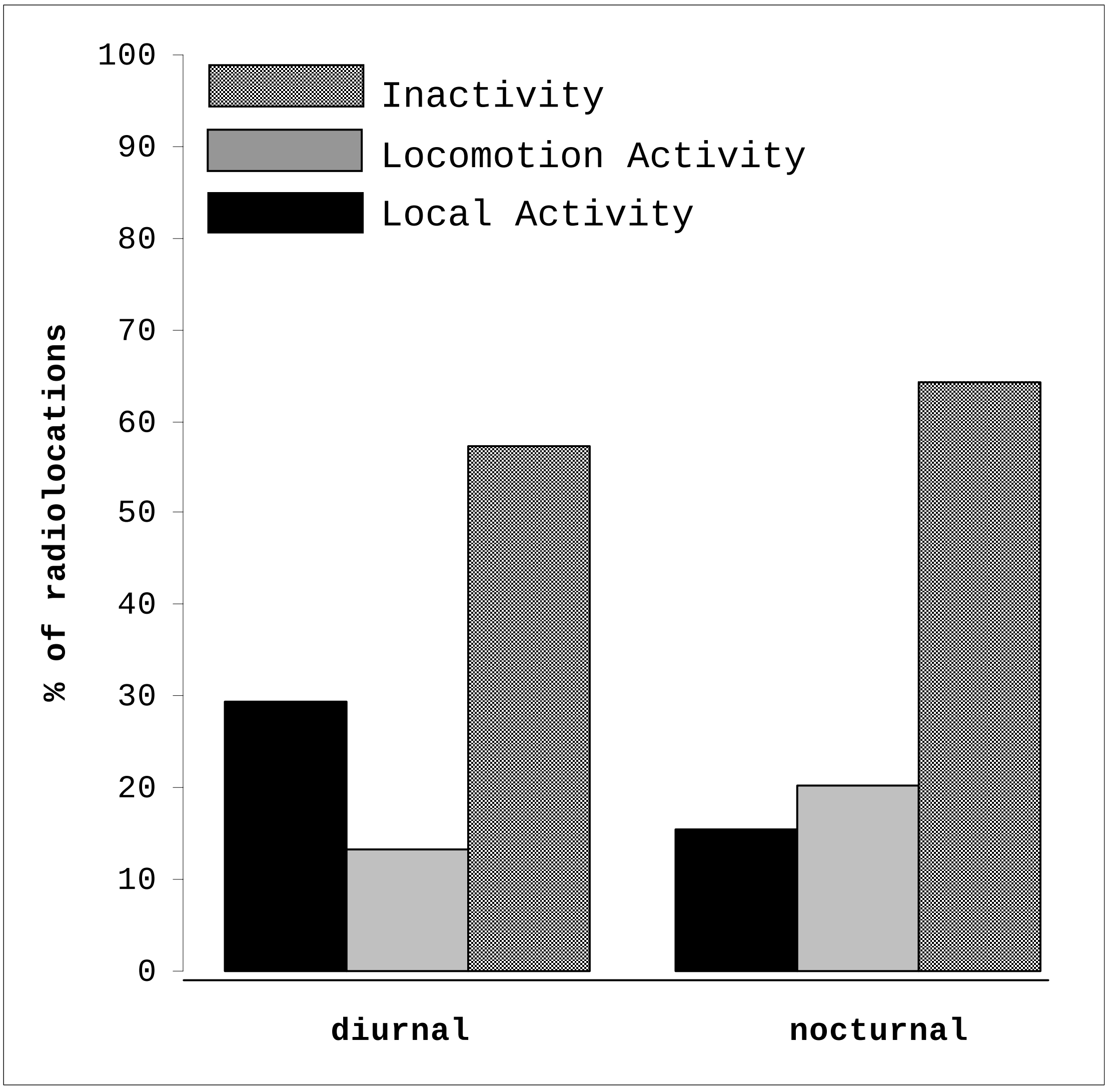

100
90
80
70
60
50
40
30
20
10
0
% of radiolocations
Inactivity
Locomotion Activity
Local Activity
diurnal
nocturnal

Fig. 3.

RESUMEN

El visón americano ha sido caracterizado esencialmente como una especie nocturna (Gerell, 1969; Birks y Linn, 1982), si bien, en general, pasa más tiempo inactivo que activo (Dunstone y Birks, 1983; Ireland, 1990), permaneciendo la mayor parte del tiempo dentro del refugio (Dunstone y Birks, 1983). El presente trabajo tiene como objetivo estudiar los ritmos de actividad de una población invasora de visón americano y evaluar las posibles diferencias entre la actividad total y la actividad de locomoción.

El estudio se realizó a lo largo de 6 km del curso fluvial del río Llobregat y a lo largo de 5 km de su afluente la riera Gavarresa. Se llevó a cabo una sesión de trampeo anual durante los meses de octubre a diciembre de 2003, 2004 y 2005 con 588 trampas noche por sesión. Los ejemplares capturados fueron anestesiados, manipulados y liberados tras su recuperación de los efectos de la anestesia. Se marcó a cada uno de los animales con un transponder magnético (Trovan Ltd., Madrid, España) y a algunos de ellos se les colocaron collares radiotransmisores de frecuencia entre 150 y 151 MHz (BioTrack, Ltd., Wareham, Dorset, UK y Tinyloc Ltd., Mataró, España).

Las radiolocalizaciones de los ejemplares se tomaron directamente cada hora entre el amanecer y el atardecer sin triangulación, dado que los movimientos del visón siguen el curso fluvial (Gerell, 1970; Birks y Linn, 1982; Ireland, 1990; Bonesi, 1996). Adicionalmente, se realizaron doce seguimientos intensivos de 24 h con localizaciones cada 30 min. Para ello, se emplearon dos tipos de transmisores. Los transmisores Tipo 1 incluían un sensor de actividad que permitió detectar si el animal estaba activo o inactivo: son capaces de detectar y de discriminar entre actividad local (actividad sin desplazamiento), actividad de locomoción (actividad con desplazamiento) e inactividad total. Los transmisores Tipo 2, no incluían sensor de actividad local, por lo tanto sólo detectaron actividad de locomoción o no locomoción (actividad local + inactividad total) de acuerdo con la intensidad de la señal. Se registraron un total de 903 radiolocalizaciones con los transmisores de Tipo 1, y 702 con los de Tipo 2.

En el presente trabajo se han analizado las posibles diferencias debidas a la utilización de uno u otro tipo de transmisor comparando la actividad de locomoción detectada por cada tipo de transmisor. Para realizar dicho análisis, se ha utilizado un modelo lineal general mixto (GLMM). Posteriormente, y empleando también GLMMs, se ha estudiado la actividad total (actividad local + actividad de locomoción) *versus* la inactividad total; y la actividad de locomoción *versus* la actividad local. En todos los casos, se han comprobado los posibles efectos del sexo, la edad, el fotoperíodo, el mes, el caudal del río y la precipitación media por día.

Para el estudio se obtuvieron datos de 19 visones (11 con transmisor Tipo 1 y 8 con transmisor Tipo 2). Dado que se ha comprobado que existen diferencias significativas entre los transmisores (Tabla 1 y Fig. 1), para realizar el análisis de la actividad se han utilizado únicamente los datos suministrados por los transmisores Tipo 1.

A lo largo del día, los animales presentan un 27,6 % de actividad local y un 13,9 % de actividad de locomoción (Figs. 2 y 3). Ninguno de los factores analizados ejerce un efecto significativo en el análisis de la actividad total (Tabla 1 y Fig. 2). En el caso del análisis de la actividad de locomoción, el sexo y la edad muestran un efecto positivo (Tabla 1; Figs.1b y 1c), mientras que la precipitación presenta un efecto negativo (Tabla 1; Figs.1b y 1c).

En base a los resultados obtenidos, cabe concluir que los visones estudiados están inactivos la mayor parte del tiempo coincidiendo con los resultados de los estudios de Dunstone y Birks (1983), y Ireland (1990). El comportamiento activo de locomoción resultó mayoritariamente nocturno, pero en menor porcentaje a lo esperado según otros estudios realizados (Ireland, 1990; Dunstone, 1993, Palazón y Ruiz-Olmo, 1997; Garin *et al.*, 2002a; Garin *et al.*, 2002b). Sin embargo, es predecible que el patrón de actividad de los carnívoros coincida con el de sus presas más comunes (Laundré y Keller, 1981; Zielinski *et al.*, 1983; Ferguson *et al.*, 1988; Gerell, 1969; Bonesi *et al.*, 2000). Por lo tanto, la menor nocturnidad de los ejemplares estudiados se explica por la composición de su dieta. La causa reside en que las poblaciones de visón americano en el área de estudio basan su dieta principalmente en cangrejo de río, peces y micromamíferos (Melero *et a*l., enviado). Tanto los cangrejos de río como los peces pueden ser capturados ya sea durante el día como durante la noche, pero los micromamíferos (*Mus musculus* y *Apodemos sylvaticus*) con mayor representación en la dieta del visón presentan hábitos fundamentalmente nocturnos. Finalmente, el efecto negativo de la precipitación sobre la locomoción se explica por el carácter marcadamente mediterráneo del área, en la que las tormentas otoñales, con regímenes de lluvias escasas pero intensas, permiten argumentar los resultados obtenidos.

Growth of culled and not culled American mink populations in Northeast Spain and their potential distribution: are culling campaigns effective?*

Yolanda Melero[1], Santiago Palazón[1,2], and Joaquim Gosàlbez[1].

[1]Department of Animal Biology (Vertebrates). University of Barcelona. Av. Diagonal, 645. 08028. Barcelona, Spain.

[2]Department of Environment and Hausing. Generalitat de Catalunya. Doctor Roux, 80.

Y. Melero: Tel: +34 934035370. Fax: +34 934064426. E-mail: melero@ub.edu.
S. Palazón: Tel: +34 935674200. E-mail: santiago.palazon@gencat.net
J. Gosàlbez: Tel: +34 934021451. Fax: +34 934064426. E-mail: jgosalbez@ub.edu.

Corresponding author: Yolanda Melero

Running headline: Population growth and potential distribution of American mink

* Journal of Zoology London, submitted.

Abstract

Growth rate of four American mink populations located in Catalonia was studied. Three populations were subjected to culling campaigns and a fourth one was set as control population (not culled). Hence, effectiveness of the culling campaigns to eradicate American mink was tested by comparing growth rates of culled populations and control population. Moreover, the potential distribution of the American mink in Catalonia was studied using geographical information systems (GIS) to predict the distribution and to assist in planning the management of its control. Populations presented a growth rate close to 1, with significant differences among them. Thus, populations seem to be close to the stability and are able to recover annually from the eradication suffered. Potential distribution of American mink ranges from almost all over Catalonian watercourses, with the preferred areas located in the Northeast. Thereafter, we encourage the governments and the administrations to maintain culling campaigns focusing specially on limiting the spread of the American mink population instead of focusing on eradication, taking as target areas the borders of their distribution with special attention to the possible spread towards preferred areas.

Keywords: American mink, Culling campaigns, Population growth rate, Potential distribution.

Introduction

The American mink's (*Mustela vison* Schreber, 1777) original populations were distributed through North America, except for the North of the Polar Artic, the Artic Circle and the southern states of the United States (Banfield, 1974; Linscombe *et al.*, 1982). In the early 20th century, American mink were introduced to Europe, Russia and South America for fur-farming (Linn and Birks, 1989; Dunstone, 1993). Feral populations became established and widespread following deliberate release (Russia) or accidental escapes (elsewhere) (Bonesi and Palazón, 2006). In Spain, mink were first recorded in wild in 1978 (Delibes and Amor, 1978). Currently, there are several established populations distributed in the Northern half of the country (Palazón and Ruiz-Olmo, 1998; Ruiz-Olmo *et al.*, 1999).

While some feral populations are suffering a decline in North America, the American mink has become a serious conservation problem in Europe, Russia and South America since its introduction for fur farming. The species has an impact on wildlife, game and fishing species and livestock. It can reduce and locally exterminate potential prey species, such as the Spanish river crab (*Austropotamobius pallipes*), the Iberian desman (*Galemys pyrenaicus*), the Mediterranean watervole (*Arvicola sapidus*) both in France and the Iberian Peninsula (Palazón and Ruiz-Olmo, 1998; Palomo and Gisbert, 2002), the watervole (*Arvicola terrestris*) in the United Kingdom (Strachan and Jefferies, 1993; Barreto *et al.*, 1998; Macdonald and

Strachan, 1999) and communities of birds (Craik, 1999; Ferreras and Macdonad, 1999; Nordström and Korpimäki, 2004). Moreover, the American mink can also perturb the population structure of other riparian predators such as the polecat (*Mustela putorius*), the European mink (*Mustela lutreola*) and the otter (*Lutra lutra*) due to the competition among them and to Aleutian Disease (ADV) of which mink is considered a vector (Mason and Macdonald, 1983; Mañas *et al.*, 2001; Sidorovich and Macdonald, 2001).

In Europe, some governments are currently developing American mink control programmes to eradicate the invading populations, and to protect the native prey and competitor species. In Spain, since 1999, a programme funded under the aegis of different regional governments and the Spanish government, and with the help of five European Life programmes (02MNAT/8604 European Life Program 2001-2008, MMA 2008) has been ongoing to control the American mink and to protect the European mink.

To make decisions for the management and the control of American mink, it is essential to know the demographic parameters, the distribution and the potential distribution of the populations. In Spain, several studies describing the distribution of the species have been made (Palomo and Gisbert, 2002), although models for its potential distribution have not been published. Moreover, demographic studies are scarcer and basic parameters as population growth rate are not well known.

This paper studies the growth rate of populations located in Catalonia. Three populations were subjected to culling campaigns (data provided by the Department of Environment and Housing, Catalonian Government); meanwhile one was not being culled (control population). We wanted to check not only growth rate of populations located in Catalonia but also we wanted to test if also to test if culling campaigns to eradicate them are effective. In addition, the potential distribution of the American mink in Catalonia was studied using geographical information systems (GIS) since the capacity to predict the distribution and the abundance of mink could assist in planning the management of its control.

Materials and Methods

Study area

The study was carried out in four areas located in Catalonia (Northeast Spain). Three of them correspond to the culled populations and the fourth one to the not culled population (control area). The first area is located in Northeast Catalonia (2º 50' E, 42º 10' N) along 35 km of the river Fluvia The altitude of this area ranges between 20-150 m. The rest of them are situated in Central-East Catalonia. The second area (1º 52' E, 41º 32' N) comprises 30 km of the river Llobregat and its altitude ranges between 100-160 m. The third area (1º 45' E, 41º 51' N) comprises 27 km of the river Cardener and its altitude ranges between 150-520 m. The control area (1º 53'E, 41º

49’ N) comprises 20 km of the river Llobregat and 12 km of its tributary the Gavarresa river with an altitude between 160-350 m.

The riparian forest found in the areas is dominated by *Arundo donax*, *Typha latifolia*, *Phragmites communis*, *Juncus* spp., *Rubus ulmifolius*, *Rosa canina*, *Populus alba, Ulmus minor* and *Salix alba.* As Mediterranean areas, strong autumn rainfalls and the subsequent flooding reduce vegetation coverage yearly. The Eurasian otter (*Lutra lutra*) and the spotted genet (*Genetta genetta*) share the riparian habitat with the American mink, while European mink are absent from the areas. Main potential preys of mink are Cyprinids, Salmonids, the American crayfish (*Procambarus clarkii*) and rodents such as *Mus musculus* and *Apodemus sylvaticus* (Palomo and Gisbert, 2002; Melero *et al.*, submitted).

Mink trapping

Trapping seasons all around Catalonia have been carried out since 1999 by the Department of Environment and Housing of the Catalonian Government between July-January and February-June to eradicate American mink. Data obtained during the first trapping seasons (July-January, 2002-2006) before mink start mating (postbreeding census) from three of these culled populations were selected for this study. Animals were live-trapped in single cage traps (15 x 15 x 60 cm), the number of trap-nights used in each of the three areas varied among years. Traps were placed on both riverbanks at a distance of 300-400 m aproximately, and checked every day.

After immobilization with 0.15 ml of ketamine (Imalgéne, Rhone Merieux, Lyon, France) and 0.03 ml of medetomidine (Domtor, Pfizer SA, Madrid, Spain), animals were sacrificed following ethical guidelines and Catalonian and Spanish laws about capture and sacrifice of animals and wildlife.

Four trapping campaigns were conducted in Llobregat and Gavarresa rivers, between October and December 2003, 2004, 2005 (1,876 trap-nights each year) and 2006 (750 trap-nights) in the control population. Animals were live-trapped following the methods described above, but they were not sacrificed. After the immobilization with ketamine and medetomidine, the captured animals were manipulated and classified as either new capture or recapture. Captured animals were marked with a transponder, which was later read using a transponder reader (Trovan Ltd., Madrid, Spain) in order to distinguish new captures from recaptures. After manipulation and once the minks were fully recovered, all captured animals were released into the same area where they had been captured.

Trapping in all the populations was carried out during the post breeding seasons when all animals were older than 5 months and there were no juvenile minks (<4 months old). Individuals were classified by sex and age (subadults 5-8 months old; or adults >8 months old) based on the combination of teeth condition and weight (Maran and Robinson, 1996).

Population Growth Rate and Density

The annual population growth rate is defined by the equation $N_{t+1} = \lambda_t N_t$, where N_t is the population size in year *t* and λ_t is the annual population growth rate. This is known as a model for discrete-time geometric population growth since growth rate is calculated for each year (*t*) using a non-structured population model (individuals are not divided into classes or stages) in a randomly variable environment (Morrison and Doak, 2002). We can therefore, calculate the growth rate of the population using the relationship $\lambda_t = N_{t+1} / N_t$.

The population parameter λ_t was calculated for culled and control populations to observe the effectiveness of culling on the population using the equation $\lambda_t = N_{t+1} / N_t$ and setting N as the number of mink captured/trap-nights. By dividing mink captured into trap-nights the error due to the different number of trap-nights used among different years is corrected. When data of consecutive years was lacked we calculated population growth rate between first and next year with data (i.e. 2003 to 2005 instead of 2003 to 2004) and then gived the annual rate λ_t as an estimation (λ_t) of the real rate based on the formula $\lambda_{t+i} = \lambda_t * \lambda_{t+1} * \lambda_{t+2} * \ldots \lambda_{t+I}$ (Morrison and Doak, 2002). Significant differences between the growth rates and densities were tested using a Kruskal-Wallis test.

Mink Potential Distribution

Geographical information systems (GIS) were used to model the possible distribution of mink in Catalonia. The framework of the model integrates three components that define mink distribution. The first is concerned to characterizing the geo-referenced habitats of Catalonia (CORINE; Land_cover200 version 1) and reconciling them with the species habitats preferences and requirements. We created categories classifying the habitats into 3 classes based on previous studies and on our own experience (1 = not suitable for mink, 2 = suitable for mink, 3 = preferred by mink) (Appendix I) which comprise habitat type's preferences of the species. That provides a geo-referenced habitat map of Catalonia re-categorized in patches of preferred habitats selected by the species. The second component is concerned to the geo-referenced watercourses map of Catalonia (MIRAMON, v5.3.Bt., Generalitat de Catalunya) since the species inhabits close to the watercourses and therefore its distribution is determined by the presence of water. The geo-referenced map was re-categorized into two classes (0 = no water presence, 1 = water presence). Finally, the third component relates to the land's elevation, Digital Elevation Model map (DEM) of Catalonia was re-categorized into two classes (0 > 1200 m, 1 < 1200 m). Maximum altitude for mink found in Spain and Catalonia was set in 1200 meters following literature (data from the Department of Environment and Housing, Generalitat de Catalunya).

All maps were converted from vectorial maps to rasterized maps into 100 m rasters and then re-categorized into the corresponding classes. Once maps were categorized, they were overlapped and multiplied obtaining a single map that represents the potential distribution of the species based on their biological needs and preferences. We also add the current distribution map of the species provided by the Department of Environment and Housing, Catalonian Government (Figure 1).

All GIS analyses were made using the GIS software packages ArcView 3.2 (Enviromental System Research Institute, Inc., USA) and GRASS 6.0.2RC4 (SSI/MPBA group, Italia).

Results

Population Growth Rate and Density

Details of the trapping campaigns conducted in the four studied areas are reported in Table 1. Population growth rate (λ_t) per years of culled and control populations resulted as follows. Area 1: $\lambda_{2003} = 0.97$, $\overline{\lambda}_{2004} = 0.97$ (since $\overline{\lambda}_{2002\text{-}04} = 0.98 = \lambda_{2003} * \lambda_{2004}$), $\lambda_{2005} = 0.03$. Area 2: $\lambda_{2003} = 0.82$, $\lambda_{2004} = 0.82$, $\overline{\lambda}_{2005} = 0.82$ (since $\overline{\lambda}_{2002\text{-}05} = 0.56 = \lambda_{2003} * \lambda_{2004} * \lambda_{2005}$), $\lambda_{2006} = 0.92$. Area 3: $\lambda_{2003} = 1.16$, $\overline{\lambda}_{2004} = 1.16$ (since $\overline{\lambda}_{2002\text{-}05} = 1.31 = \lambda_{2003} * \lambda_{2004}$), $\lambda_{2005} = 1.15$. Control area: $\lambda_{2004} = 0.9$, $\lambda_{2005} = 1.06$, $\lambda_{2006} = 1$ (Figure 2). Significant differences among population growth rates of the studied populations were found ($H = 8.62$, $df = 3$, $p = 0.04$).

The control population showed a mean age-sex ratio of 1: 1.4: 1.6: 2.1 (subadult female, adult female, subadult male, adult male). Ratios for culled populations were not possible to calculate since it was not possible to register all data on sex and age of captured animals.

Mink Potential Distribution

Rasterized and reclassified maps of habitat, elevation and rivers are shown in the figure 3a-c. Figure 3d shows the potential distribution map of American mink based on the product of two maps: the habitat map and the elevation map. Figure 3e shows the potential distribution map of American mink following watercourses based on the product of three maps: the habitat map, the elevation map and the watercourse river map.

Discussion

Exterminating a pest is generally difficult, very intensive culling is usually required to drive an abundant and productive population into decline. Moreover, reducing density facilitates the increase of growth rates by increasing its reproductive rate in order to compensate the density lost produced by the reduction of the survival (Macdonald *et al.*, 2000). The population growths obtained in the culled studied areas seem to be a consequence of this recovery capacity of the species. The intrinsic rate of increase indicates the facility of the population to recover from perturbation. By reducing survival of these populations and therefore their density an effect on the demography occurred in this way that populations do not decrease but they maintain their densities approximately constant. In fact, growth rate of either culled populations or control population differed but were all close to the stable growth rate, except in the case of the annual population growth (2004-2005) of the first culled area. In this last case and since it is the only one showing a decrease, it may be due to a less effective trapping campaign rather than to a real decrease in the population. Anyway, trapping campaigns in the following years will give the correct answer for this result. Hereafter, in relation to population growth being close to the stable growth rate, the results do not only inform about the non effectiveness of the culled population but also informs about the fact that American mink populations in Catalonia are at their local carrying capacity in the habitat were they live in (since $\lambda = 1$, approximately). Moreover, when animals are removed from a population, compensation may occur, so that natural mortality or emigration is lower in the following year, allowing the population to grow faster than it did before the cull (Macdonald *et al.*, 2000). Established populations are not expected to continue growing more in density but they can spread over new territories; meanwhile, culled populations would reduce this spread since new born minks probably would not look for far away territories if they have empty territories in the area of birth that belonged to previous culled adults (Macdonald *et al.*, 2000). Hence, it seems that trapping has some potential for controlling mink populations even though it is very unlikely that control could ever be implemented at a high enough level to render mink extinct on any river system. Currently, it seems that culling is effective if we try to limit a population, rather than to exterminate it (Dunstone, 1993; Boitani, 2001).

Another control method is the sterilisation of captured animals. However, this method is more expensive and difficult to carry on. Hence, it will result in occupied home ranges and few or zero newborns, then there will be low or no emigration of the population. Thus, this method is effective in limiting the population but it is not effective in exterminating it, and hence, possibly it doesn't differ significantly from the culling method.

It is also important that strategies that attempt American mink control consider the criteria for identifying target areas. For maximum effectiveness, any mink killing should be carefully planned, tackling questions such as where and when effort should be prioritized, how large an area should be targeted, and according to what pattern of revisitation. Limiting a population implies targeting the culling campaigns especially in the borders of the species' distribution and keeping a preferable attention on its preferred areas. Although there is very little information available on dispersal in mink, they are generally considered good dispersers, since minks have been recorded travelling distances 10 km from the site of birth (Dunstone, 1993) and one mink was found 40 km from their birth place (Gerell, 1970). Thus, trapping campaigns should be settled between these distances inside and outside the borders of the distribution to assure that no minks are able to spread. The maps obtained are useful to set the target areas, it seems North-Eastern areas of

Catalonia are the more suitable areas for mink establishment. Nowadays, American mink is established in the Central-Eastern and Central-Northeastern part of Catalonia where the fur farms from where they escaped were located. From there it would be relatively easy to spread to more Northern areas along the rivers Muga, Ter, Tordera, Besos and Llobregat. This area is inhabited by potential protected preys such as waterfowls and watervoles *Arvicola sapidus*. However, the otter also inhabits the area and it can imply a reduction of the mink spread. Southern Catalonia resulted to be a suitable area for mink. In fact, the path along the river Ebro, where some minks have been already seen, resulted suitable for mink. Mink colonisation of river Ebro in Catalonia is considered as a potential way for mink to contact the remaining Spanish European mink population (Palazón *et al.*, 2003) by its Eastern side. In consequence, either the eradication of the American mink populations or the limitation of their spread in Catalonia should be settled as a main target for the conservation of both potential preys and European mink.

In general, limiting its spread may be more feasible than eradicating its populations. Culling campaigns have achieved the extermination goal in some specific areas. In the archipelago of the Western Isles of Scotland the eradication programme appears to have reduced the number of minks dramatically over much of the area (771 km^2) (Moore *et al.*, 2003). In a group of islands of the Archipelago National Park in South-Western Finland (72 km^2), a mink eradication project was carried out using a portable leaf-blower (normally used to collect fallen leaves) and trained dogs; since

1998, no minks have been trapped and the eradication is considered successful (Genovesi, 2000). In Estonia, a mink eradication project was successfully realised on Hiiumaa Island (1000 km^2); during the campaign, 52 minks were trapped using 10 leg-hold traps, and success of the eradication was monitored through collection of mink presence signs in the breeding season (Genovesi, 2000). All these areas present characteristics that make success possible, they are small and isolated areas, with no active mink fur farms. Despite these localised successes, mink extermination has thus far proven to be impractical (Dunstone 1993; Boitani, 2001). A remarkable example is the United Kingdom, where the Ministry of Agriculture, Fisheries and Food, failed to eliminate American mink in the 1960s despite capturing of 5,000 mink in England and Wales (King, 1983). The same occurs in Spain, where more than 1,300 minks where captured during 2003 and 2004 but mink populations have not been reduced. In Catalonia, since 2002 over 400 minks have been captured; however, the populations do not seem to decrease as it has been shown by the results and as it has been pointed by the Department of Environment and Housing (Palazón, 2006).

Acknowledgements

We would like to thank “Universitat de Barcelona”, “Generalitat de Catalunya” and 02MNAT/8604 Life Project for funding this study. Y.M. is supported by a FPU

Fellowship granted by the Spanish “Ministerio de Ciencia y Tecnología” (AP 2002-2653). The Catalonian eradication program is funded under the aegis of five European LIFE Projects and the Spanish Ministry. We are grateful to the Department of Environment and Housing, Catalonian Government, to the “Agentes Rurales” and Fish Keepers for carrying on the Catalonian culling campaigns and providing field and data material for this study. We also thank Albert Roura, Berto Minobis, Teresa Montras and Joana Martelo for their collaboration in taking samples in the field, and Arnau Roma for the English correction. We are really grateful to Laura Bonesi, Francesca Jordan, Irene Ortolan, Katjia Mignozzi, and all the staff of the “Departimento di Biologia, Università di Trieste, Italia” for their teaching and help in carrying on the GIS analyses.

References

Banfield, A.W.F. 1974. The mammals of Canada. University Toronto Press. Toronto.

Delibes, M. and Amor, F. 1978. On the distribution and status of Spanish carnivores. Abstr. II Congr. Theriol. Intl, 146. Brno, CSSR.

Barreto, G.R., Rushton, S.P., Strachan, R. and Macdonald, D.W. 1998. The role of habitat and mink predation in determining the status and distribution of water voles in England. Animal Conservation. 1, 129-137.

Birks, J.D.S. and Dunstone, D. 1991. Mink. In: The handbook of British mammals. G.B. Corbet and S. Harris, eds. Balckwell Scientific Publications, Oxford, Reino Unido. Pp. 406-415.

Boitani, L. 2001: Carnivore introductions and invasions: their success and management options. In: Gittleman, J.L., Funk, S.M., Macdonald, D.W., and R.K. Wayne, eds. Carnivore conservation. Cambridge, UK, Cambridge University Press. Pp. 123–144.

Bonesi, L. and Palazón, S. (2007) The American Mink in Europe: status, impacts, and control. Biological Conservation. 134, 470-483.

Craik, J.C.A. 1999. Long-term effects on North American mink *Mustela vison* on seabirds in western Scotland. Bird Study. 44, 303-309.

Dunstone, N. 1993. The mink. London: Poyser Natural History.

Ferreras, P. and Macdonald, D.W. 1999. The impact of American mink *Mustela vison* on water birds in the upper Thames. Journal of Applied Ecology. 36, 701-708.

Genovesi, P. 2000. Guidelines for Eradication of Terrestrial Vertebrates: a European Contribution to the Invasive Alien Species Issue. Council of Europe, Strasbourg, 61 pp.

Gerell, R. 1970. Home ranges and movements of the mink *Mustela vison* Schreber in southern Sweden. Oikos. 21, 160-173.

King, C. 1983. Factors regulating mustelid populations. Acta Zoologica Fennica. 174, 217–220.

Linn, I. and Birks, J.D.S. 1989. Mink (Mammalia; Carnivora; Mustelidae): correction of a widely quoted error. Mammal Review. 19, 175-179.

Linscombe, G., Kinler, N. and Aulerich, R.J. 1982. Mink *Mustela vison*. In: Chapman, J.A. and J.A. Feldhamer, eds. Wild mammals of Norteamérica: Biology, Management and Fisheries, Los Angeles. Pp. 629-643.

Macdonald, D.W. and Rushton, S. 2003. Modelling space use and dispersal of mammals in real landscapes: a tool for conservation. Journal of Biogeography. 30, 607-620.

Macdonald, R. A. and Strachan, R. 1999. The mink and the watervole: analyses for conservation. Oxford: Wildlife Conservation Research Unit and Enviroment Agency.

Macdonald, D.W., Tattersall, F.H., Johnson, P.J., Carbone, C., Reynolds, J., Langbein, J., Rushton, S.P. and Shirley, M. 2000. Managing British mammals: case studies from the hunting database. Oxford, UK, Wildlife Conservation Research Unit.

Mañas, S., Ceña, J.C., Ruiz-Olmo, J., Palazón, S., Domingo, M., Wolfinbarger, J.B. and Bloom, M.E. 2001. Aleutian mink disease parvovirus in wild riparian carnivores in Spain. Journal of Wildlife Diseases. 37, 138-144.

Mason, C. and Macdonald, S. 1986. Otters: ecology and conservation. Cambridge University Press, Cambridge.

Moore, N.P., Roy, S. S. and Helyar, A. Mink (*Mustela vison*) eradication to protect ground-nesting birds in the Western Isles, Scotland, United Kingdom. New Zealand Journal of Zoology. 30, 443-452.

Morrison, W.F. and Doak, D.F. 2002. Quantitative Conservation Biology. Theory and practice of population viability analysis. Sinauer, MA, USA.

Nosdström, M. and Korpimäki, E. 2004. Effects of island isolation and feral mink removal on bird communities on small islands in the Baltic Sea. Journal of Animal Ecology. 73, 424-433.

Nummelin J., and Högmander, J. 1998. Uusi menetelmä minkin poistamiseksi ulkosaaristoss on tuottanut yviä toloksia. Metsästäjä. 1/98, 16-18. (In Finnish).

Palazón, S. and Ruiz-Olmo, J. 1998. El visón europeo (*Mustela lutreola*) y el visón americano (*Mustela vison*) en España. Ministerio de Medio Ambiente, Organismo Autónomo de Parques Nacionales. Madrid. 133 pp.

Palazón, S., Ruiz-Olmo, J., Gosàlbez, J., Gómez-Gayubo, A., Ceña, J.C. and Ceña, A. 2003. Trends in distribution of the European mink (*Mustela lutreola* L., 1761) in Spain: 1950-1999. Mammalia. 67, 473-484.

Palomo, J. and Gisbert, J. 2002. Atlas de los Mamíferos terrestres de España. Organismo Autónomo de Parques Nacionales. DGCNA_MIMAM, Madrid, Spain. (In Spanish).

Ruiz-Olmo, J. and Delibes, M. 1998. Conservation Plan for the otter in Catalonia: biology and ecology. Generalitat de Catalunya. Environmental Notebook Documents nº 6. 145 pp.

Birks, J.D.S. and Linn, I.J. 1982. Studies of the home range of the feral mink (*Mustela vison*). Symposium Zoological Society of London. 49, 231-257.

Ruiz-Olmo, J., Palazón, S., Bueno, F., Bravo, C., Munilla, J. and Romero, R. 1999. Distribution, status and colonization process of the American mink *Mustela vison* in Spain. Journal of Wildlife Research. 2, 30-36.

Sidorovich, V.E. and Macdonald, D.W. 2001. Density dynamics and changes in habitat use by the European mink and other native mustelids in connection with the American mink expansion in Belarus. Netherlands Journal of Zoology. 51, 107-126.

Strachan, R. and Jefferies, D.J. 1993. The water vole *Arvicola terrestris* in Britain 1989-1990: its distribution and changing status. Vincent Wildlife Trust, London, UK.

Table 1. Number of captured minks during 2003-2006 in the studied areas.

Captures	Area 1	Area 2	Area 3	Control area
2002	2	5	1	No data
2003	No data	No data	No data	38
2004	14	No data	3	33
2005	3	6	12	35
2006	No data	5	No data	15
Reason for trapping	Eradication	Eradication	Eradication	Study

Figure 1. Current American mink distribution in Catalonia.

Figure 2. Representation of the annual population growth rates based on N_t = number of captured mink/trap-nights. Circles = area 1; rhombus = area 2; triangles = area 3; and squares = control area.

Figure 3a. Habitat map of Catalonia (CORINE) reclassified into three classes depending on mink habitat suitability. 3b. Elevation map of Catalonia (DEM) reclassified into two classes depending on mink habitat suitability. 3c. Watercourse system map of Catalonia. 3d. Potential distribution map based on the combination of habitat and elevation suitability for mink. The map is the result of the multiplication of the reclassified habitat and elevation map of Catalonia, both rasterized to 100 x 100 m. 3e. Potential distribution map based on the combination of habitat, elevation suitability maps for mink and watercourse systems. The map is the result of the multiplication of the reclassified habitat and elevation map and the watercourse map of Catalonia, all them rasterized to 100 x 100 m.

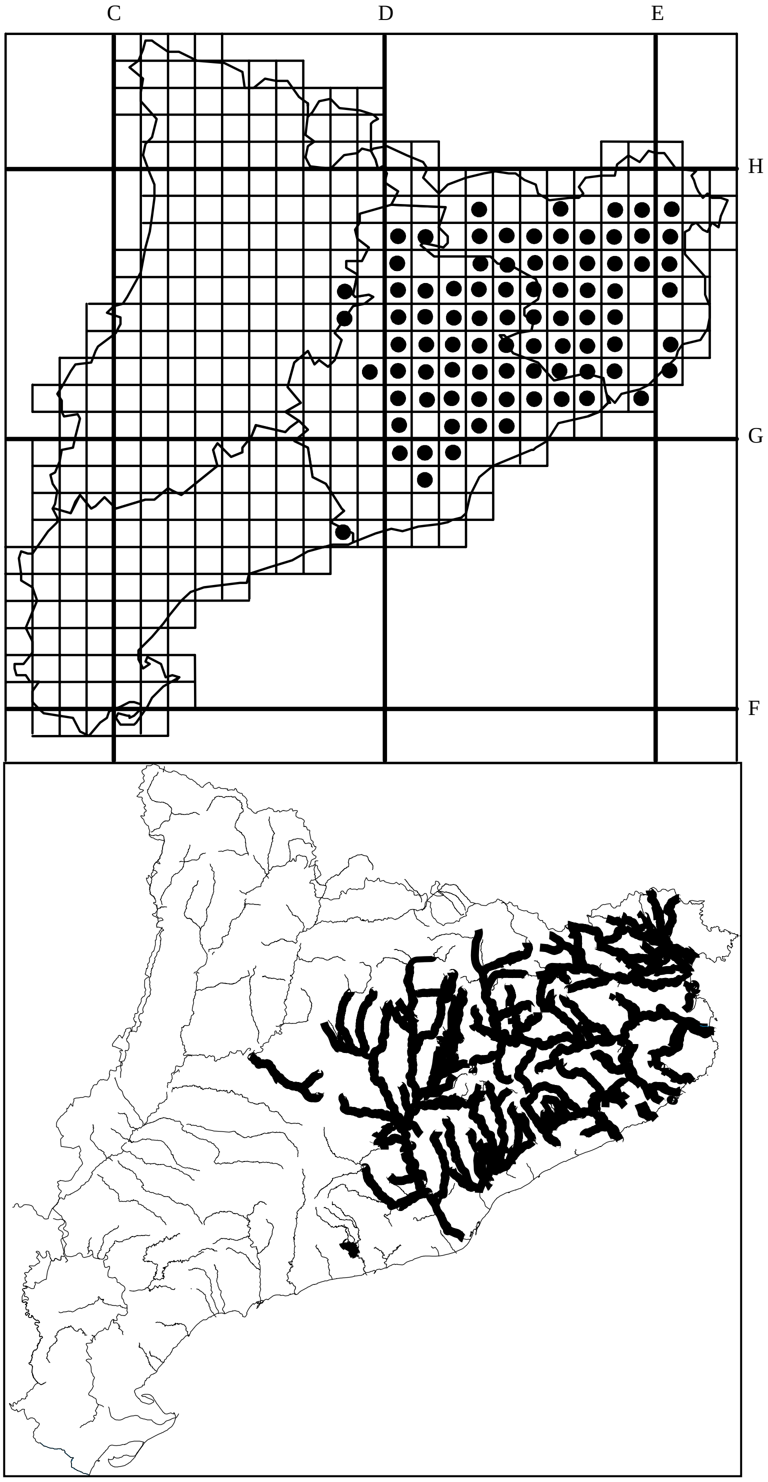


Figure 1.

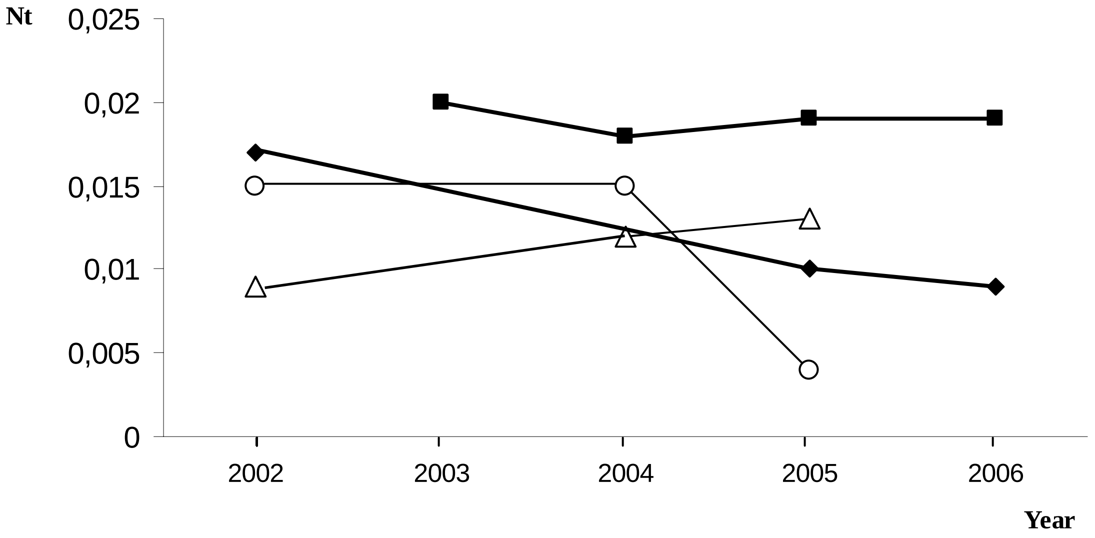


Figure 2.

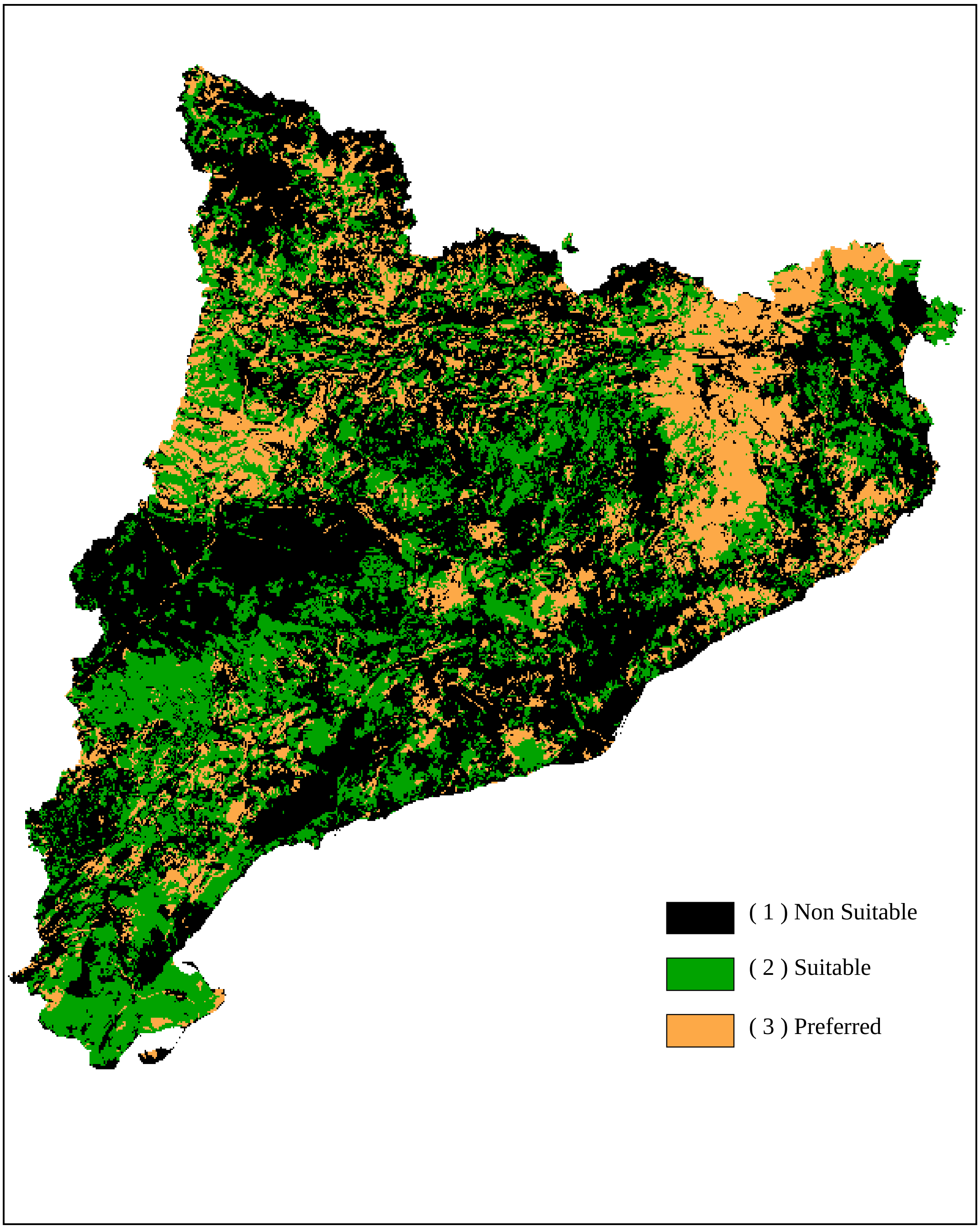


Figure 3a.

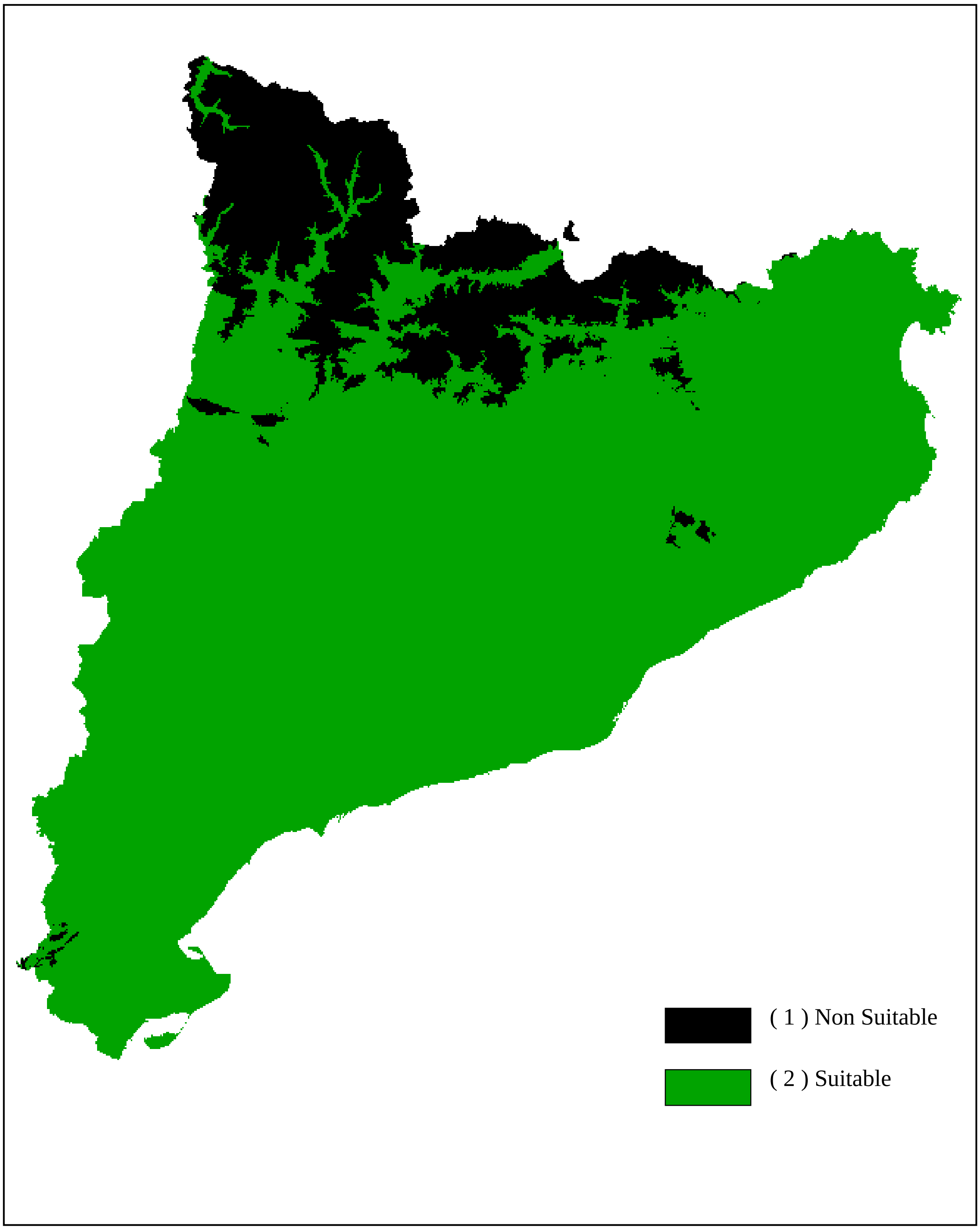


Figure 3b.

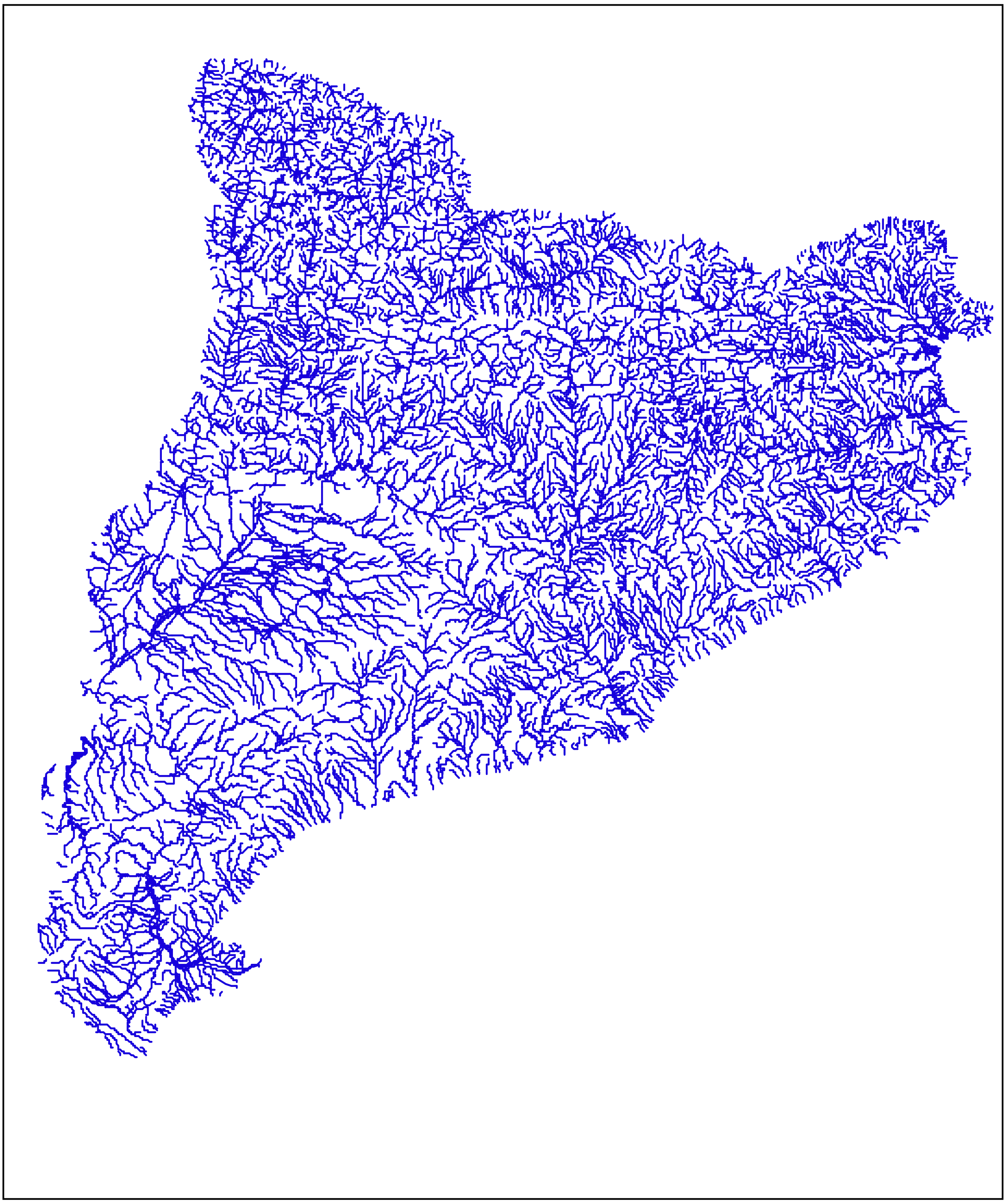


Figura 3c.

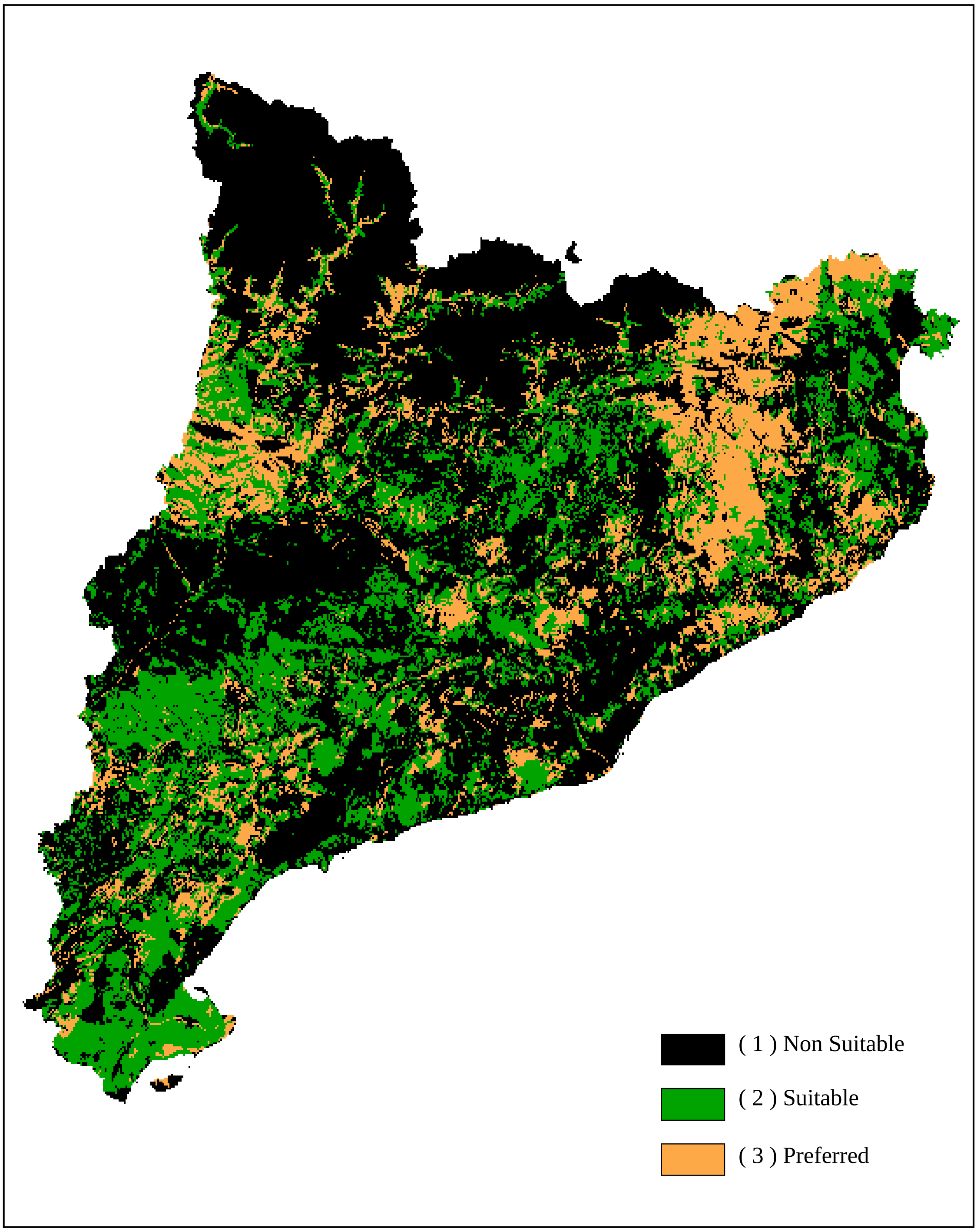


Figure 3d.

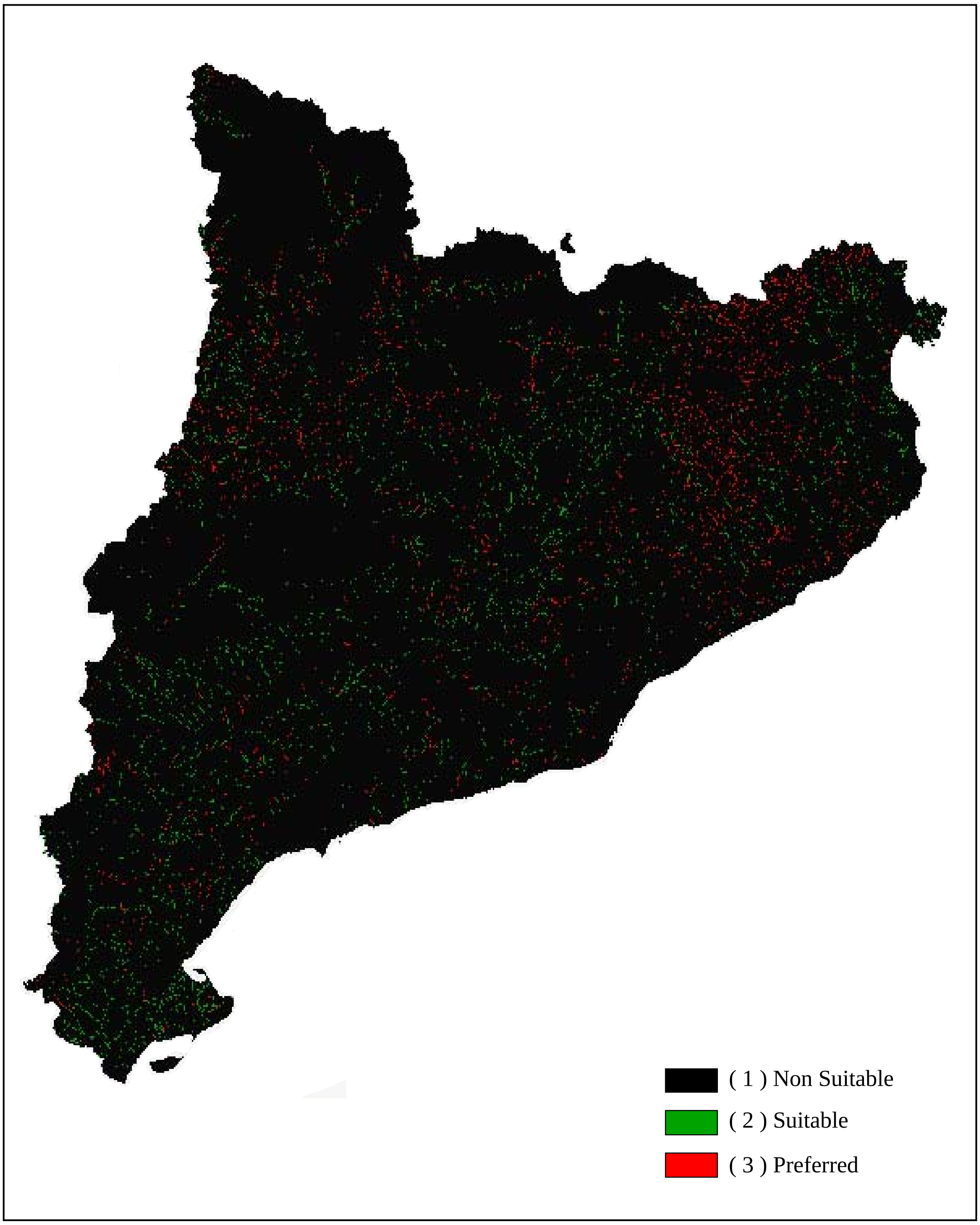


Figura 3e.

RESUMEN

Desde la introducción del visón americano en Europa (Linn and Birks, 1989; Dunstone, 1993), la especie se ha convertido en un problema ecológico que implica la necesidad de su control. La metodología de control hasta el momento se basa en el descaste de las poblaciones invasoras. El presente estudio tiene como objetivo determinar el grado de crecimiento de cuatro núcleos poblacionales localizados en Cataluña, testar la eficacia del proceso de descaste sobre estas poblaciones y proporcionar la distribución potencial de la población del visón americano en Cataluña.

El estudio se realizó sobre cuatro poblaciones de visón americano, tres de ellas sometidas a descaste y otra no sometida a descaste (población control), todas ellas situadas en cuencas fluviales de Cataluña, abarcando una extensión total de 27 a 35 km de curso fluvial. Se llevó a cabo una sesión de trampeo anual durante la época post-reproductora (Julio-Enero) de 2002 a 2006 (salvo contadas excepciones en las que el trampeo no resultó posible) en poblaciones sometidas a descaste y de 2003 a 2006 en la población control.

Los datos de captura obtenidos en las sucesivas campañas de muestreo han sido utilizados para calcular el crecimiento anual de cada una de las poblaciones basándose en la fórmula: $\lambda t = Nt+1 / Nt$. Asimismo, se han comparado los crecimientos poblacionales mediante un test Kruskal-Wallis.

La distribución potencial de la especie en Cataluña se ha determinado mediante Sistemas de Información Geográfica (GIS). Dicha distribución, representada por un mapa, se ha obtenido a través de la superposición de tres mapas (hábitat, altitud y cursos de agua) con parámetros categorizados en preferible, óptimo o no óptimo para

la especie según sus características biológicas empleando los programas ArcView 3.2 (Enviromental System Research Institute, Inc., USA) and GRASS 6.0.2RC4 (SSI/MPBA group, Italia).

Las tres poblaciones muestran tasas de crecimiento significativamente diferentes (H = 8,62, df = 3, p = 0,04) pero próximas al valor de estabilidad (λ = 1). Área 1: λ_{2003} = 0,97; λ_{2004} = 0,97, λ_{2005} = 0,03. Área 2: λ_{2003} = 0,82, λ_{2004} = 0,82, λ_{2005} = 0,82, λ_{2006} = 0,92. Área 3: λ_{2003} = 1,16, λ_{2004} = 1,16, λ_{2005} = 1,15. Área control: λ_{2004} = 0,9, λ_{2005} = 1,06, λ_{2006} = 1 (Figure 2). Los resultados de la distribución potencial se representan en la Figura 3.

Los resultados muestran la capacidad de recuperación de las poblaciones de visón americano ante el descaste efectuado. La disminución en su tasa de supervivencia parece verse compensada por un aumento en la tasa de fecundidad de la población, como ya se ha observado en otras poblaciones (Macdonald *et al.*, 2000). Por lo tanto, el control de la especie, mediante este procedimiento, no parece que pueda ser lo suficientemente eficaz como para eliminar las poblaciones asentadas en los sistemas fluviales estudiados en Cataluña. Sin embargo, el aumento de la tasa de mortalidad implica un aumento de territorios vacíos no ocupados por ningún individuo y, por lo tanto, una disminución de la tasa de emigración dado que los subadultos no tendrán la necesidad de dispersarse en busca de nuevos territorios disponibles (Macdonald *et al.*, 2000). En consecuencia, la efectividad del control de las poblaciones se encuentra en limitar su dispersión. En Cataluña, es aconsejable que el trampeo y control de las poblaciones sea intenso en los límites de las áreas de distribución de la especie, especialmente en la parte norte en base a los mapas obtenidos, y en el sur por el peligro que supone para el visón europeo. Dunstone (1993) registró desplazamientos de individuos de visón americano de 10 kilómetros, y Gerell (1970) de 40 kilómetros; por lo tanto, para mayor seguridad se aconseja que las campañas de descaste en los límites de distribución se realicen entre estos valores de distancia en ambas direcciones, del límite dentro y fuera del área de distribución. También se aconseja aplicar las mismas distancias en los límites de zonas de especial interés como parques naturales, o zonas protegidas.

Evaluating sign surveys as a way to monitor the American mink in Spain*

Yolanda Melero [1], Joana Martelo, Santiago Palazón [1, 2], Joaquim Gosàlbez [1]
& Laura Bonesi[3]

[1] Department of Animal Biology (Vertebrates). University of Barcelona. Av. Diagonal, 645. 08028. Barcelona, Spain.
[2] Department of Environment and Housing. Generalitat de Catalunya. Doctor Roux, 80. 08017. Barcelona, Spain.
[3] Department of Biology, University of Trieste, Via Weiss 2, 34127 Trieste, Italy

Y. Melero: Tel: +34 934035370. Fax: +34 934064426. E-mail: melero@ub.edu.
S. Palazón: Tel: +34 935674200. E-mail: santiago.palazon@gencat.net
J. Gosàlbez: Tel: +34 934021451. Fax: +34 934064426. E-mail: jgosalbez@ub.edu.

Corresponding author: L. Bonesi. Tel: + 04 05582010. Email: lbonesi@units.it

Keywords: American mink, Survey, Otter's survey methodology, Transect length, Detection probability.

---

* Wildlife Research, submitted.

Abstract

The American mink is an elusive mustelid that is monitored mostly through the detection of its signs, namely footprints and scats. In Europe, the American mink has been monitored using the standard otter survey methodology developed specifically for the otter, which requires walking transects of 600 m spaced at least 5 km apart. We test whether the standard otter survey methodology is appropriate for surveying mink as well as otters. We studied a high-density population of mink along a 9 km stretch of river between December and April. Monthly surveys were conducted and scats and footprints recorded within 100 m sections along the river. The results indicated a seasonal variation in signs recovery, with the months of December, January and February being the best ones for surveying. Transects of 600 m detected mink between 72% and 90% of the times in all months excluding March when detection was as low as 56%. Detection probabilities between replicated surveys, calculated with the method of Mckenzie (2002), were relatively high (75%). Taken all together the results suggest that the standard otter survey methodology was sufficiently adequate to detect mink only at certain times of the year and that seasonality should be taken into account when designing the sampling strategy and the length of the sampling units (transects).

INTRODUCTION

The American mink (*Mustela vison*) is a semi-aquatic mustelid imported from North America to Spain in the 1950s for the fur farming industry (Bravo & Bueno 1992). Following escapes and intentional releases, this species has now established seven feral populations (Ruiz-Olmo *et al.* 1997, Zabala & Zuberogoitia 2003) and is a cause of concern because of the considerable negative impacts that it can potentially have on native species through competition, predation, or disease spread (Palazón & Ruiz-Olmo 1997, Mañas *et al.* 2001, Delibes *et al.* 2004). In particular, Spain hosts some of the few remaining populations of the European mink, one of the most endangered mammals in Europe (IUCN, 2003) and these populations are now threatened by the American mink through competition and possibly disease spread (e.g. Maran *et al.* 1998, Mañas *et al.* 2001).

Monitoring the distribution of invasive alien species is an important part of management plans aimed at mitigating their impacts (Wittenberg & Cock 2001). Indeed, monitoring the American mink distribution is one of the stated priorities in the conservation plan of the European mink in Spain (02MNAT/8604 European Life Program 2001-2008, MMA 2006). Because crepuscular and nocturnal mustelids, like mink, are difficult to observe, indirect methods of monitoring need to be developed and tested for these species. Mink, like other semi-aquatic species such as the Eurasian otter (*Lutra lutra*), can be monitored indirectly because they leave signs in the form of footprints and scats (faeces) along the river banks and these signs can be relatively easily found and hence recorded (Bonesi & Macdonald 2004). However, in order to estimate the presence of mink through surveys for its signs, no specific methodology has been developed and tested but instead, in most cases, the standard Eurasian otter survey methodology (e.g. Strachan & Jefferies 1996, Reuther 2000), developed specifically for otters, has been used for mink as well (e.g. Crawford 2003). This methodology requires 600 m long transects to be surveyed for signs along water bodies. Each transect is separated from the next by sections, usually about 5-8 km long, which are not surveyed (Strachan & Jefferies 1996, Reuther 2000). While a 600 m transect has been determined to be sufficiently long to ensure a high probability to find otter signs when otters are present even in areas with relatively low otter density (Strachan & Jefferies 1996, Reuther 2000), no studies, to our knowledge, have determined whether the same distance is also appropriate for surveying mink.

Mink and otters differ in several aspects. Otters are larger than mink, they have longer home ranges, and live at lower densities (Green *et al.* 1984, Jefferies *et al.* 1986; Ruiz-Olmo *et al.* 1995) (Birks 1986; Dunstone 1993). It is also possible that mink and otters adopt different marking behaviours irrespective of their relative density. Indeed, when they are both present it is much easier to find otter spraints than mink scats in spite of the higher density of mink while it has been observed that tracks, in areas with suitable substrata, tend to be a more common sign for mink than for otters (Bonesi & Macdonald 2004). Differences in the seasonality of their yearly reproductive cycles may also affect sign deposition by these species. Timings of reproduction in otters can be unseasonal, such as in Britain, or seasonal with births more common in spring and summer, but in general, otters tend to be less synchronised in their breeding season than other carnivores (Kruuk 1995). However, the frequency of spraints recovery often shows seasonal trends (Conroy and French 1991). Mink instead, are seasonal breeders and more signs tend to be found during the reproductive and dispersal seasons (Bonesi & Macdonald 2004). All these differences may affect the frequency and location of signs deposited by these species and therefore the assumption that a 600 m transect, as in the standard otter survey, is appropriate for mink as it is for otters needs to be verified.

Besides the problem of establishing the minimum distance to be searched in order to detect mink when present there is also the problem of establishing the consistency of the results of these surveys: if one repeats the survey within a short time span, what is the probability that the result would be the same, i.e. that mink signs would be found in the same river sections? This probability is known as ‘detection probability’ (MacKenzie *et al.* 2002). When surveying for mink signs, one can commit two kinds of errors: failing to detect mink when they are present because their signs are absent (false negative) or recording mink as present by mistakenly recording signs of another species as signs of mink (false positive). If we assume that the population is closed with no immigration, emigration, births or deaths, then errors of detection may depend principally on the kind of habitat and on the presence or absence of species with which the signs of mink could be confused. All these factors may vary between different areas, it is therefore important to establish detection probabilities in each specific case.

Given the above considerations, to assess indirect surveys for signs as a means to monitor the invasive American mink in Spain, we examined three aspects: 1) General patterns of signs deposition; 2) Minimum transect length; 3) Detection probability of mink signs.

MATERIALS AND METHODS

STUDY AREA

The study area was located in eastern Spain (1º 53'N, 41º 49' E) along the rivers Llobregat (4 km) and its tributary Gavarresa (5 km) (Figure 1). The average annual rainfall in the zone is 490 mm approximately and the altitude of the area ranges between 160 m and 350 m. The riparian forest is dominated by *Arundo donax*, *Typha latifolia*, *Phragmites communis*, *Juncus* spp., *Rubus ulmifolius*, *Populus alba* and *Salix* spp. As a Mediterranean area, strong autumn rainfalls and the subsequent flooding reduce vegetation coverage yearly. The Eurasian otter (*Lutra lutra*) and the spotted genet (*Genetta genetta*) shared the riparian habitat with the American mink, while European mink were absent from the area. The main preys of mink in the study area are Cyprinids, Salmonids, the American crayfish

(*Procambarus clarkii*) and rodents such as *Mus musculus* and *Apodemus sylvaticus* (Melero, Palazon, Bonesi, Gosalbez in prep.). In the past, both rivers were quite polluted by nearby industries, cities and villages, but since 1990 pollution levels have decreased thanks to the opening of several water-treatment plants (Ruiz-Olmo and Delibes 1998).

SURVEY METHOD

River shorelines were divided into contiguous sections of 100 m and searched continuously on the right and left bank for up to 10 m from the river's edge. A section is defined here as a stretch of 100 m either on the right or on the left bank. There were 80 sections on the river Llobregat and 90 sections on the river Gavarresa. Sections that were inaccessible due to vegetation density or high cliffs were removed from the analysis, leaving 40 sections on the river Llobregat, 17 on the right bank and 23 on the left, and 76 on the river Gavarresa, 36 on the right bank and 40 on the left bank. During a single survey all sections were checked. In November 2004, the study area was searched for the first time and signs were removed, and these data were excluded from the analyses. From December 2004 until April 2005 the whole study area was surveyed once a month with 20-30 days intervals between surveys. Each survey took on average 2-3 days to be completed. All surveys were carried out at least 3 days after the last raining day following the methodology used in England by Bonesi & Macdonald (2004). All signs were removed so they were not counted more than once. Type of sign (track or scat), number of signs, date and geographical coordinates (UTM) were recorded.

IDENTIFICATION OF SIGNS

Two kinds of mink signs were recorded, mink scats and mink footprints. Mink scats can be distinguished from those of the Eurasian otter and the spotted genet based on their smell and appearance. Mink scats are usually compact and are about 0.9 cm in diameter and present a strong characteristic foetid odour easy to recognise. Otter spraints vary in shape but they have a characteristic sweet-musky odour. Genet faeces found in the riparian habitat can be similar to mink scats, but they are usually larger than those of mink (about 1.3 cm in diameter) and do not have the characteristic smell of mink scats (see Livet and Roeder 1987; Dunstone 1993). Mink footprints can be differentiated from those of the otter and the genet based on the size and their appearance. Otter footprints are clearly bigger than those of minks. Meanwhile, genet footprints only show four toes without claws while mink and otter show five toes with claws (see Dunstone 1993; Livet and Roeder, 1987; Sidorovich 1999).

ANALYSES

General patterns: The number of positive sections, that is sections with at least one mink sign, was examined with respect to the month of collection, river, and bank side. In this latter case one separate test for each river was carried out. To test for differences with respect to the month of collection, a χ^2 test was used that compared observed with expected frequencies, where the expected frequencies were represented by an equi-distribution of mean values for each time period. A contingency table test was used to test differences in river and bank side.

Minimum transect length: The distance between consecutive signs was measured separately for each survey and the frequency distribution of distances plotted. Signs that were separated by non-accessible sections were excluded from the analysis. To identify the minimum survey distance a cumulative curve depicting the proportion of positive transects as a function of the distance walked to find the first sign was calculated (Gallant *et al.* 2007). To generate this curve, also known as rarefaction curve (Kohn *et al.* 1999, Eggert, Eggert & Woodruff 2003), 50 random points were selected along the studied rivers and transects of increasing length with a step of 50 m were built around each random point, up to a distance of 2000 m. When transects included missing sections within 500 m from the random point, a new point was chosen to avoid the bias produced by the missing data. Transects are defined here as stretches of river of variable length while sections are defined here as stretches of river 100 m long as described above. The left and right banks were treated here as independent. For each transect length, the number of transects with signs was counted. This procedure was carried out separately for each of the five surveys. The relationship obtained was described by plotting a cumulative curve defined by the function:

(1) $A(x) = ax / (b + x)$

where x is the maximum distance (m) of riverbank searched, $A(x)$ is the cumulative number of transects with mink signs up to the given distance, a is the asymptote and b is the rate of decrease of the non-linear slope when x increases. The Levenberg-Marquardt estimation method for the non-linear regression module in SPSS (version 9.0 for Windows) was used to estimate a and b values. The starting value was set at 1 for parameter estimations, and computations were terminated and final parameters values accepted when the relative reduction between successive residual sum of squares was < 1.000E-08, following Gallant *et al.* (2007). The statistical software R version 2.2.1 was used for all other analyses (R Foundation for Statistical Computing http://www.R-project.org).

Probability of detection: the probability of committing detection errors (false positives and false negatives) was calculated following the method of MacKenzie *et al.* (2002) and using the software PRESENCE (www.proteus.co.nz). This method estimates detection probability by comparing surveys that are carried out at short intervals within a short time period so that one can assume that the population is 'closed', i.e. that there are no changes in the number of individuals so that changes in the proportion of sites occupied between surveys can be attributed exclusively to sampling errors. To calculate detection probability we used data collected from the surveys of December, January and February as they were carried out within a relatively short time period. The method of MacKenzie *et al.* (2002) requires sites to be independent; as the home range length in the area was about 1 km (Melero pers.obs.), 600 m transects along the river were alternatively selected to increase the probability that different individuals were occupying the sites considered in the analysis. These 600 m transects are referred to as 'sites' for this analysis. The standard error around the non-biased estimates was calculated using the nonparametric bootstrap method (n = 200 bootstraps samples) as suggested by MacKenzie *et al.* (2002).

RESULTS

GENERAL PATTERNS

An average of 23% (SD = 5, n = 5) of the 100 m sections were found to be positive during surveys, of these 16% (SD = 4, n = 5) contained scats and 7% (SD = 2, n = 5) contained footprints. The surveys carried out in March and April had fewer positive sections than the surveys between December and February (Figure 2), and the difference was statistically significant at the 0.10 probability level (Mann-Whitney U = 0.00, p = 0.10, $n_{\text{dec-feb}} = 3$ and $n_{\text{mar-apr}} = 2$, one tailed test). If sections of 600 m were considered instead of sections of 100 m, then the proportion of positive sections was 58%, 90%, 90%, 74%, and 68%, for the months between December and

April (for all n = 19). There was no statistically significant difference in the proportion of positive sections of 100m between the two studied rivers (χ^2 = 10, df = 9, p = 0.27, n = 10) and between banks, where banks were considered separately for each river (Llobregat: χ^2 = 10, df = 6, p = 0.13, n = 10; Gavarresa: χ^2 = 10, df = 9, p = 0.35, n = 10).

MINIMUM TRANSECT LENGTH

When plotting the frequency distribution of the distances between signs it was observed that 71% of signs were found within 600 meters of each other and 90% within 900 meters (Figure 3a). When plotting each month separately it was found that while the frequencies of the surveys conducted in December, January and February peaked markedly at lower distances, that of April and particularly that of March showed a rather different distribution (Figures 3b and 3c). When considering the average distance of signs in each survey (Dec = 339 m; Jan = 378 m; Feb = 380 m; Mar = 656 m; Apr = 427 m) in relation to the number of positive sections found in each survey (Dec = 26; Jan = 28; Feb = 28; Mar = 12; Apr = 19) a significant negative correlation was observed as expected, whereby when more sections were positive the distance between them was also shorter (Pearson correlation coefficient = -0.91, p = 0.015, n = 5).

Cumulative curves representing the percentages of positive transects in each month are shown in Figure 4. If we consider the standard 600 m transect used in the otter surveys, we find that walking this distance would have detected mink presence in 74% to 90% of cases in the months of December, January, February, and April (Figure 4a-c, 4e), while in March it detected mink presence only in 56% of cases (Figure 4d). In March it was necessary to walk up to 900 m to detect mink at least 80% of the times.

PROBABILITY OF DETECTION

Eight sites, each 600 m long, were selected for this analysis. The naïve estimate of the percentage of positive sites considering the surveys of December, January and February was 100%, meaning that signs were found at least once in all the eight sites considered. The mean detection probability for these months was 75%. By decreasing the site length to 100 m and selecting one site every kilometre (n = 9), which is the average home range length for a mink in the area, detection probability decreases to 63%.

DISCUSSION

Our results show that, under the studied conditions, the standard otter survey methodology was sufficiently adequate for surveying mink. This is supported by two results in particular: (i) when mink were present, walking a transect of 600 m was enough to find mink signs at least three out of four times in any of the studied months apart from March (Figure 4a-e); and (ii) detection probabilities calculated across different months, excluding March and April, and using transects of 600 m were relatively high (75%) indicating that signs were consistently found in the same transects.

The results were however influenced by seasonal effects. In this study, the months of December, January and February were the best months for surveying. These three months were relatively comparable in terms of the proportion of positive sections (Figure 2), distances between signs, and transect length (Figure 4a-e). March and April showed instead a significantly lower proportion of positive sections (Figure 2), distances between signs were greater, and in March one needed to walk longer to find signs, while this was not the case for April (Figure 4e). April seemed to be an intermediate case between the three winter months and the month of March. Indeed, while April was more similar to March in terms of the proportion of positive sections with signs (Figure 2) it was more similar to the months between December and February when transect length was considered (Figure 4a-c), and intermediate between the winter months and March when distance between signs were considered.

A seasonality effect in the detection of mink signs, with a peak in the mating season followed by a lowering immediately after, has been observed also in other studies (e.g. Robinson 1987, Bonesi & Macdonald 2004). The mating season, that takes place between February and early April at northern Latitudes, is a period of high movement for mink because males cover greater distances to maximise their reproductive success (Yamaguchi et al. 2004) and marking with scats possibly also increases. The gestation and lactation period that follow register less movements (Chanin 1976), indeed in this period it also becomes more difficult to trap mink (Dunstone & Birks 1985, Ireland 1990). The yearly reproductive cycle is likely to influence signs deposition and hence signs detection because the number of individuals in the population, their level of activity, and possibly also their marking behaviour – all factors that affect signs detection – do vary across the cycle. This may explain why more signs tend to be found in the mating season while fewer tend to be found in the gestation and lactation seasons. However, it is interesting to note that while in the studies mentioned above the month of March was still considered a 'peak' month for finding mink signs, in the present study March was a relatively poor period for detecting mink compared to the previous months. The reasons for a decline of the number of signs detected between February and March observed in this study could be due to different factors: 1) changes in the activity levels and behaviour of mink; 2) changes in the number of mink in the area; 3) worst weather conditions in March that washed signs away; 4) surveying errors or chance events. We can exclude weather conditions as the weather in the days before and during the survey, was good for surveying with no rain and optimal visibility. It is unlikely that mink numbers sensibly changed in the area between February and March as trapping carried out during these months reported a comparable number of mink trapped per trap nights (February: 4 mink trapped per 315 trap nights = 0.0126 mink/trap night; March: 5 mink trapped per 237 trap nights = 0.0183 mink/trap night) (Melero, unpubl. data). It is unlikely that there had been changes in the activity levels and behaviour of mink due to the end of the mating season because mating was still likely to occur at the time when the survey took place, on the 9th and 10th of March. Indeed while it is expected that mating occurs and ends slightly sooner at southern latitudes than at northern ones, data on mink pregnancy and lactation for Catalonia found pregnant females in April (n = 4) and lactating females in May and June (n = 6) (Palazon, unpubl. data), in periods comparable to those observed at northern latitudes. In conclusion, there seems to be no biological or climatic explanation for the low level of sign detection in March. Moreover, sign recovery in April improved compared to March although not to the levels of the months comprised between December and February. This leaves the possibility that either surveyor errors or some other chance factor caused this low level of sign detection in March, but we don't know what could be the exact cause of this under-detection.

Detection probability between December and February, calculated with the method of Mackenzie (2002), was higher (75%) than that found in a study carried out at a comparable time of year in England (69%) (Bonesi *et al.* 2006). Although the sample size of the present study was small (n = 8) and differences in sampling design and errors around the estimates could affect the results, it is possible that the observed difference could be explained, at least in part, by differences in the density of the two populations. Mink in freshwater habitats in England have been observed to live at lower densities (e.g. Yamaguchi et al. 2004: 0.3 mink/km) than mink in the studied population (1.16 mink/km) (Melero in prep.). Higher density populations may be detected more easily than lower density ones. In higher density populations, the greater need to defend resources from competitors may induce individuals to mark more often within the territory and/or around its boundaries, by leaving more scats in prominent places and roaming more often thereby leaving more footprints (e.g. Kruuk 1992 for otters). Indeed, there is evidence that in other mustelids, such as badgers, marking per individual increases with increasing population density (Hutchings *et al.* 2002). If this was the case also for mink, then the relationship between the proportion of positive transects and the density of mink in an area would be nonlinear and possibly asymptotic. This kind of nonlinear asymptotic relationship between the density of a species and its indirect index has been observed for species such as for example the rabbit (*Oryctolagus cuniculus*) (Marchandeaua *et al.* 2006). The comparison of our results with those of the english study seems to support the hypothesis of non-linearity in the relationship between density and the indirect index based on signs also for mink, but more evidence is needed to reach a conclusive result.

Standard otter surveys require to space 600 m transects either at about 5 km intervals (Lenton *et al.* 1980). Because otters have large home ranges in the order of tens of kilometres, this spacing is likely to ensure at least one sampling unit per individual home range. However, the mink has smaller home ranges, between 1 km and 9 km, and therefore this kind of interspacing of the transects may lead to detect a smaller proportion of the population (Romanowski & Brzezinski 1997). In theory this is positive, as it leads to independence of the sampling units, but this difference must be kept in mind when using standard otter surveys to detect mink.

In conclusion, the results of this study show that a transect lenght of 600 m as for the standard otter survey is adequate to survey mink in most occasions, but that unexplained variations in the level of sign detection, such as in the month of March in this study, may occur. For this reason it may be appropriate, when possible, to either increase the transect length to 900 m or to repeat the survey at least twice.

ACKNOWLEDEGMENTS

We thank “Universitat de Barcelona”, “Generalitat de Catalunya” and 02MNAT/8604 Life Project for funding this study. Y.M. is supported by a FPU Fellowship granted by the Spanish “Ministerio de Ciencia y Tecnología” (AP 2002-2653). We are grateful to Albert Roura for their collaboration in taking samples in the field. Laura Bonesi was sponsored by the program ‘Incentivazione alla mobilità di studiosi stranieri e italiani residenti all’estero’.

REFERENCES

Bonesi, L. & Macdonald, D.W. 2004: Evaluation of sign surveys as a way to estimate the relative abundance of American mink (*Mustela vison*). - Journal of Zoology London 262: 65-72.

Bonesi, L., Strachan, R. & Macdonald, D. W. 2006: Why are there fewer signs of mink in England? Considering multiple hypotheses. - Biological Conservation 130: 268-277.

Bravo, C. & Bueno, F. 1992: Nuevos datos sobre la distribución del visón americano (*Mustela vison* Schreber) en España Central. - Ecología 6: 161-164. (In Spanish).

Chanin, P. 1976: The ecology of the feral mink (*Mustela vison* Schreber) in Devon. - Ph.D., University of Exeter, Exeter, UK.

Conroy, J.W.H. & French, D.D. 1991: Seasonal patterns in the sprinting behaviour of otters (*Lutra lutra* L.) in Shetland. - In: Reuter, C. and Röchert, R. (Ed.); Proceedings V Int. Otter Coll. Hankesbüttel 1989. Habitat , 6: 159-166.

Crawford, A. 2003: Fourth otter survey of England 2000-2002. - Environment Agency, Bristol.

Delibes, M., Clavero, M., Prenda, J., Blázquez, M. D. C. & Ferreras, P. 2004: Potential impact of an exotic mammal on rocky intertidal communities of northwestern Spain. - Biological Invasions 6: 213-219.

Dunstone, N., Birks, J. 1985: The comparative ecology of coastal, riverine and lacustrine mink *Mustela vison* in Britain. Symposium of the Zoological Society of London. No. 58: 247-262

IUCN red list of threatened species. (www.redlist.org). Gland, Switzerland: IUCN.

Eggert, L. S., Eggert, J. A. & Woodruff, D. S. 2003: Estimating population sizes for elusive animals: the forest elephants of Kakum National Park, Ghana. - Molecular Ecolology 12: 1389-1402.

Gallant, D., Vasseur, L. & Bérubé, C. H, 2007: Evaluating bridge survey ability to detect river otter presence: a comparative study. -Wildlife Biology 14(1).

Green, J., Green, R. & Jefferies, D.J. 1984: A radiotracking survey of otters *Lutra lutra* on a Perthshire river system. - Lutra 27: 85-145.

Hutchings, M. R., Service, K. M. & Harris, S. 2002: Is population density correlated with faecal and urine scent marking in European badgers (*Meles meles*) in the UK? - Mammalian Biology 67: 286-293.

Ireland, M.C. 1990: The behaviour and ecology of the American mink *Mustela vison* Schreber in a coastal habitat. - PhD thesis, University of Durham.

Jefferies, D.J. Wayre, P., Jessop, R.M. & Mitchell-Jones, A.J. 1986: Reinforcing the native otter *Lutra lutra* population in East Anglia: An analysis of the behaviour and range development of the first release group. - Mammal Review 16: 65-79.

Kohn, M. H., York, E. C., Kamradt, D. A., Haugt, G., Sauvajot, R. M. & Wayne, R. K. 1999: Estimating population size by genotyping faeces. Proceedings of the Royal Society of London, Serie B-Biological Science 266: 657-663.

Kruuk, H., Conroy, J.W.H., Glimmerveen, U. & Ouwerkrek, E.J. 1986: The use of spraints to survey populations of otters *Lutra lutra*. - Biological Conservation 35: 187-194.

Kruuk, H. 1992: Scent marking by otters (*Lutra lutra*): signalling the use of resources. - Behavioral Ecology 3: 133-140.

Kruuk, H. 1995: Wild otters. - Predation and populations. Oxford University Press.

Lenton, E., Chanin, P. & Jefferies, D. 1980: Otter Survey of England 1977-79. Nature Conservancy Council, London.

Livet, F., & Roeder, J. J. 1987: Encyclopédie des carnivores de France: la genette (*Genetta genetta*, Linnaeus, 1758). - Société Française pour l'Étude et la Protection des Mammifères 17:1–33. (In French).

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A. & Langtimm, C. A. 2002: Estimating site occupancy rates when detection probabilities are less than one. - Ecology 83: 2248-2255.

Mañas, S., Ceña, J. C., Ruiz-Olmo, J., Palazón, S., Domingo, M., Wolfinbarger, J. B. & Bloom, M. E. 2001: Aleutian mink disease parvovirus in wild riparian carnivores in Spain. - Journal of Wildlife Diseases 37: 138-144.

Maran, T., Macdonald, D. W., Kruuk, H., Sidorovich, N. V. & Rozhnow, V. V. 1998: The continuing decline of the European mink *Mustela lutreola:* evidence for the intraguild aggression hypothesis. - In: Dunstone, N. & Gorman, M. L. (Eds.); Behaviour and ecology of riparian mammals. Cambridge University Press.

Marchandeaua, S., Aubineaub, J., Bergerc, F., Gaudind, J., Roobroucke, A., Cordae, E. & Reitze, F. 2006: Abundance indices: reliability testing is crucial - a field case of wild rabbit *Oryctolagus cuniculus*. - Wildlife Biol. 12: 19-27.

Mason, C. & Macdonald, S. 1986: Otters: ecology and conservation. Cambridge: Cambridge University Press.

Palazón, S. & Ruiz-Olmo, J. 1997: El visón europeo (*Mustela lutreola*) y el visón americano (*Mustela vison*) en España. Ed. Ministerio de Medio Ambiente, Madrid. (In Spanish).

Reuther, C. 2000: Surveying and monitoring distribution and population trends of the Eurasian otter (*Lutra lutra*). Hankensbuttel, Germany: GN-Gruppe Naturshutz.

Robinson, I. H. 1987: Olfactory communication and social behaviour in the mink (*Mustela vison*). - PhD, University of Aberdeen, Aberdeen, UK.

Romanowski, J. & Brzezinski, M. 1997: How standard is the standard technique of the otter survey? - IUCN Otter Specialist Group Bulletin 14: 57-61.

Ruiz-Olmo, J. & Delibes, M. 1998: La nutria en España. Ante el horizonte del año 2000. SECEM. (In Spanish).

Ruiz-Olmo & Delibes, M. 1998: Conservation Plan for the otter in Catalonia: biology and ecology. Environmental Notebook Documents nº 6. 145 pp. MMA.

Ruiz-Olmo, J. Jiménez and López-Martín, J.M. 1995: Radio-tracking of otters *Lutra lutra* in Nother-Eastern Spain. - Lutra, 38: 11-21.

Ruiz-Olmo, J., Palazon, S., Bueno, F., Bravo, C., Munilla, I. & Romero, R. 1997: Distribution, status and colonization of the American mink *Mustela vison* in Spain. - Journal of Wildlife Research 2: 30-36.

Sidorovich, V. E. 1999. How to identify mustelid tracks. - Small Carnivore Conservation 10: 22-27.

Strachan, R. & Jefferies, D. 1996. Otter Survey of England 1991-1994. Vincent Wildlife Trust, London.

Wittenberg, R. & Cock, M. J. W. 2001: Invasive Alien Species: A Toolkit for Best Prevention and Management Practices. CAB International, Wallingford, Oxon, UK.

Yamaguchi, N., Sarno, R. J., Johnson, W. E., O'Brien, S. J. & Macdonald, D. W. 2004: Multiple paternity and reproductive tactics of free-ranging American minks, *Mustela vison*. - Journal of Mammalogy 85: 432-439.

Zabala, J. & Zuberogoitia, I. 2003: Current and historical distribution of European mink (*Mustela lutreola*) and the American mink (*Mustela vison*) in Biscay. - Small Carnivore Conservation 28: 4-6.

Figure 1. Location of the study area.

Figure 2. Percentage of sections containing scats and footprints of mink in each month. The black section of the bar represents the percentage of sections containing only footprints.

Figure 3. Frequency distribution of the distances between signs. Histogram (a) reports data for all months (n=113). Histogram (b) and (c) report data for March and April respectively.

Figure 4. Cumulative percentage of transects that would have been positive for mink as a function of transect length. Functions and a measure of their goodness of fit (r^2) are: Dec, $A = 125x / (395 + x)$, df = 39, $r^2 = 0.97$; Jan, $A = 117x / (265 + x)$, df = 39, $r^2 = 0.99$; Feb, $A = 112x / (167 + x)$, df = 39, $r^2 = 0.97$; Mar, $A = 142x / (754 + x)$, df = 39, $r^2 = 0.98$; Apr, $A = 113x / (224 + x)$, df = 39, $r^2 = 0.99$.

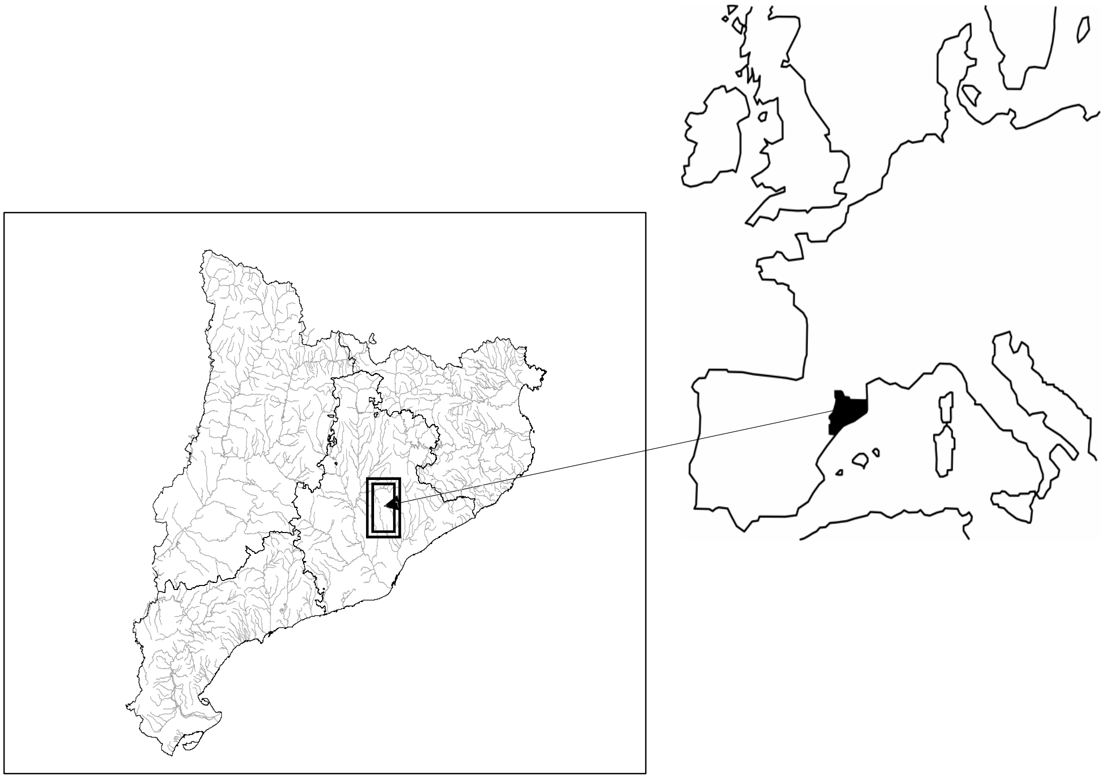


Figure 1.

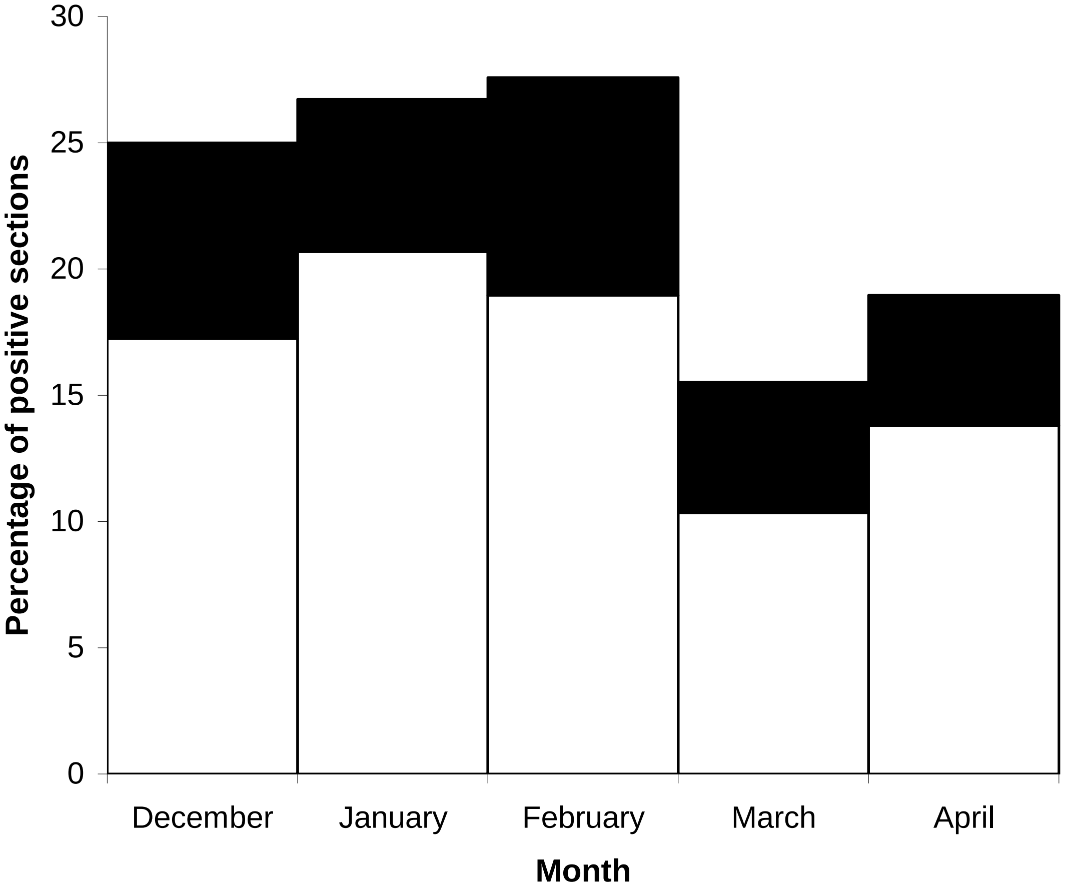

30
25
20
15
10
5
0
Percentage of positive sections
December
January
February
March
April
Month

Figure 2.

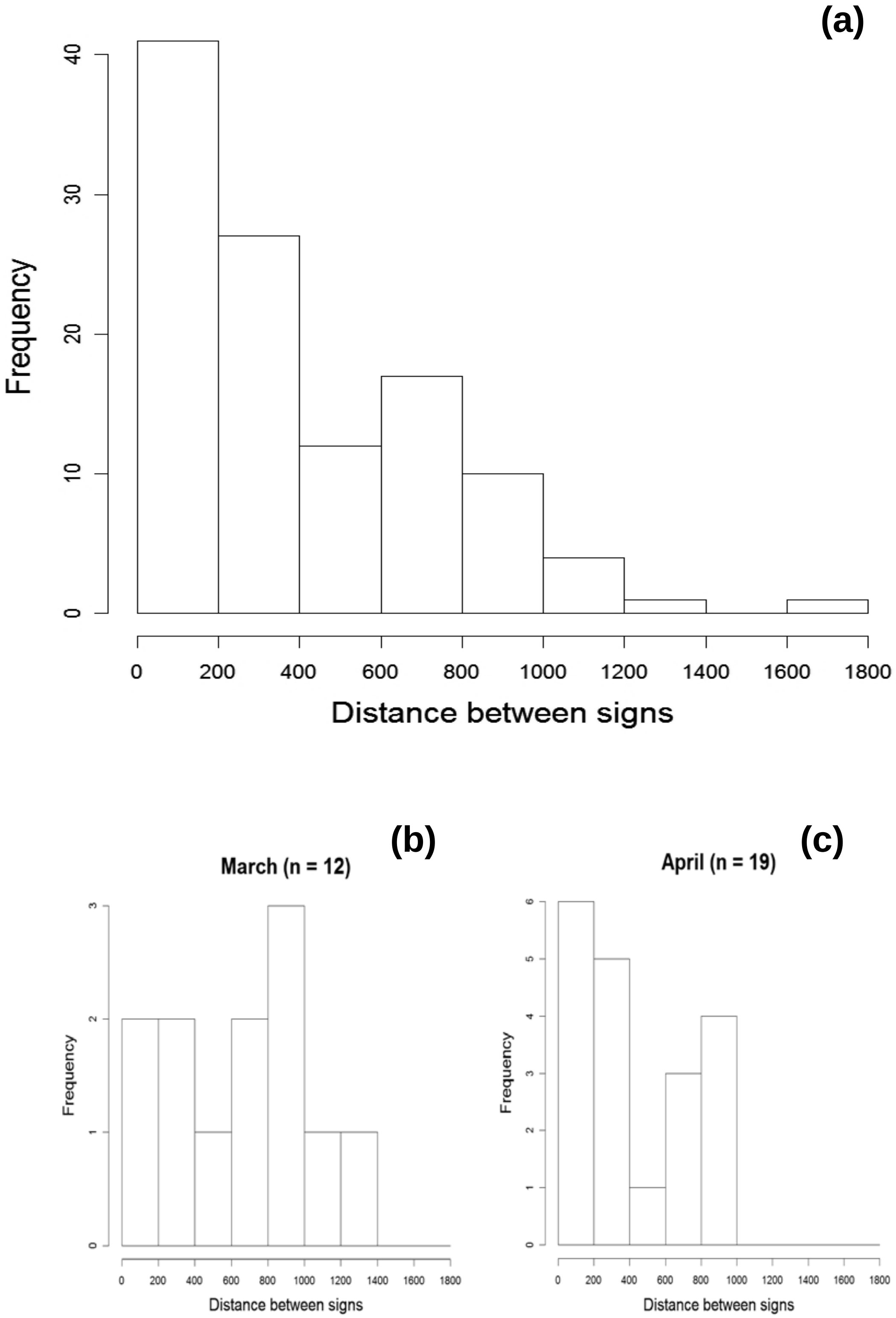
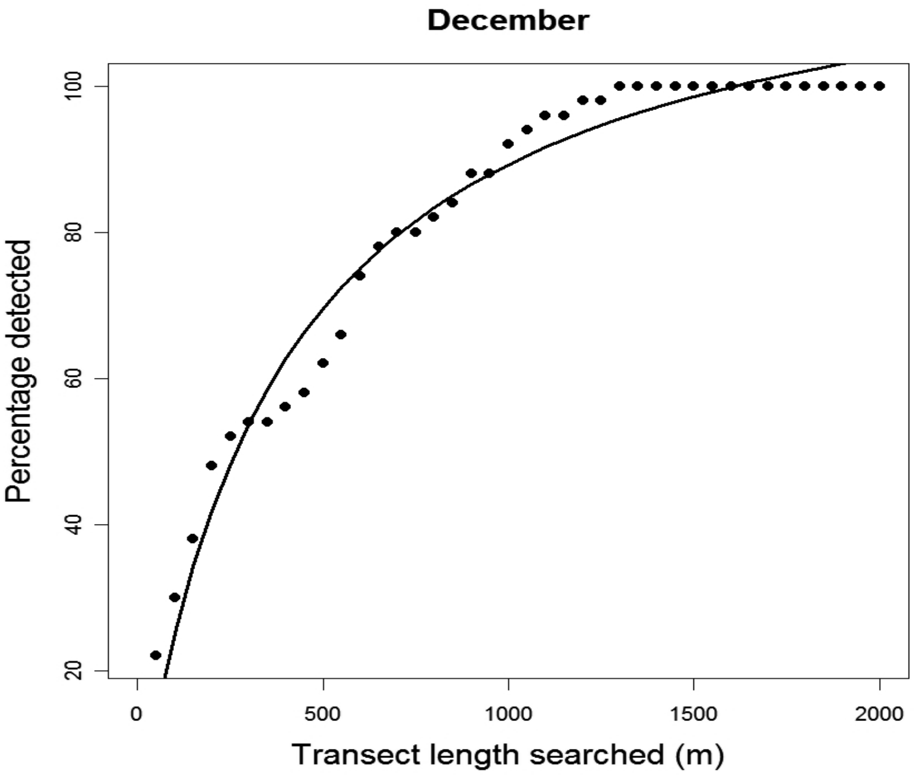

(a)
Frequency
0
10
20
30
40
0
200
400
600
800
1000
1200
1400
1600
1800
Distance between signs
(b)
March (n = 12)
Frequency
0
1
2
3
0
200
400
600
800
1000
1200
1400
1600
1800
Distance between signs
(c)
April (n = 19)
Frequency
0
1
2
3
4
5
6
0
200
400
600
800
1000
1200
1400
1600
1800
Distance between signs

Figure 3.


December
Percentage detected
20
40
60
80
100
0
500
1000
1500
2000
Transect length searched (m)

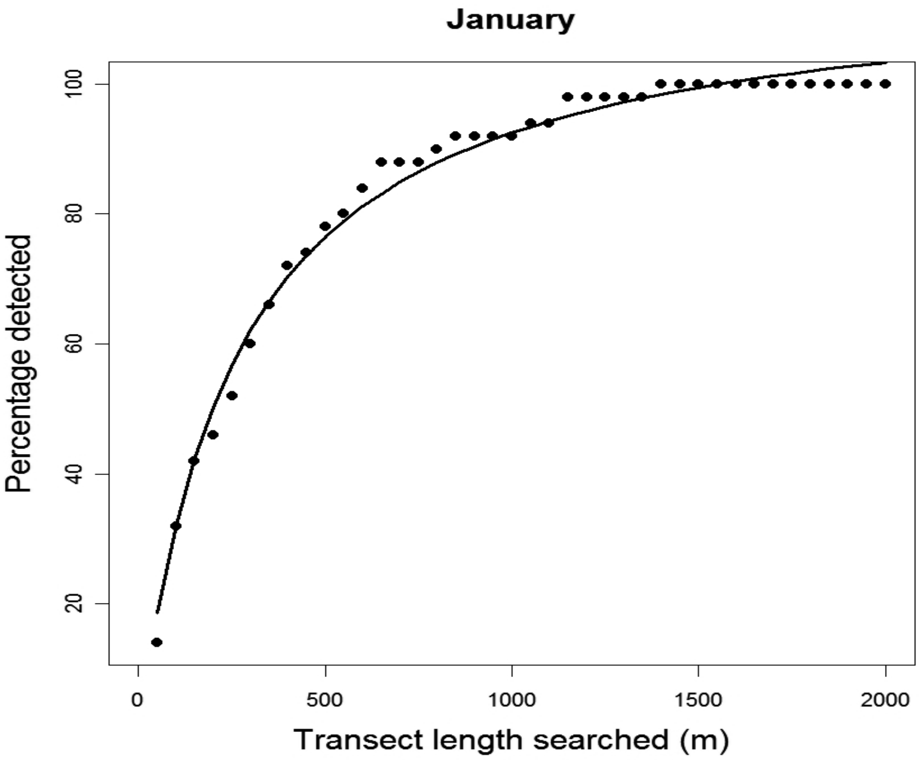

January
Percentage detected
20
40
60
80
100
0
500
1000
1500
2000
Transect length searched (m)

Figura 4a-b

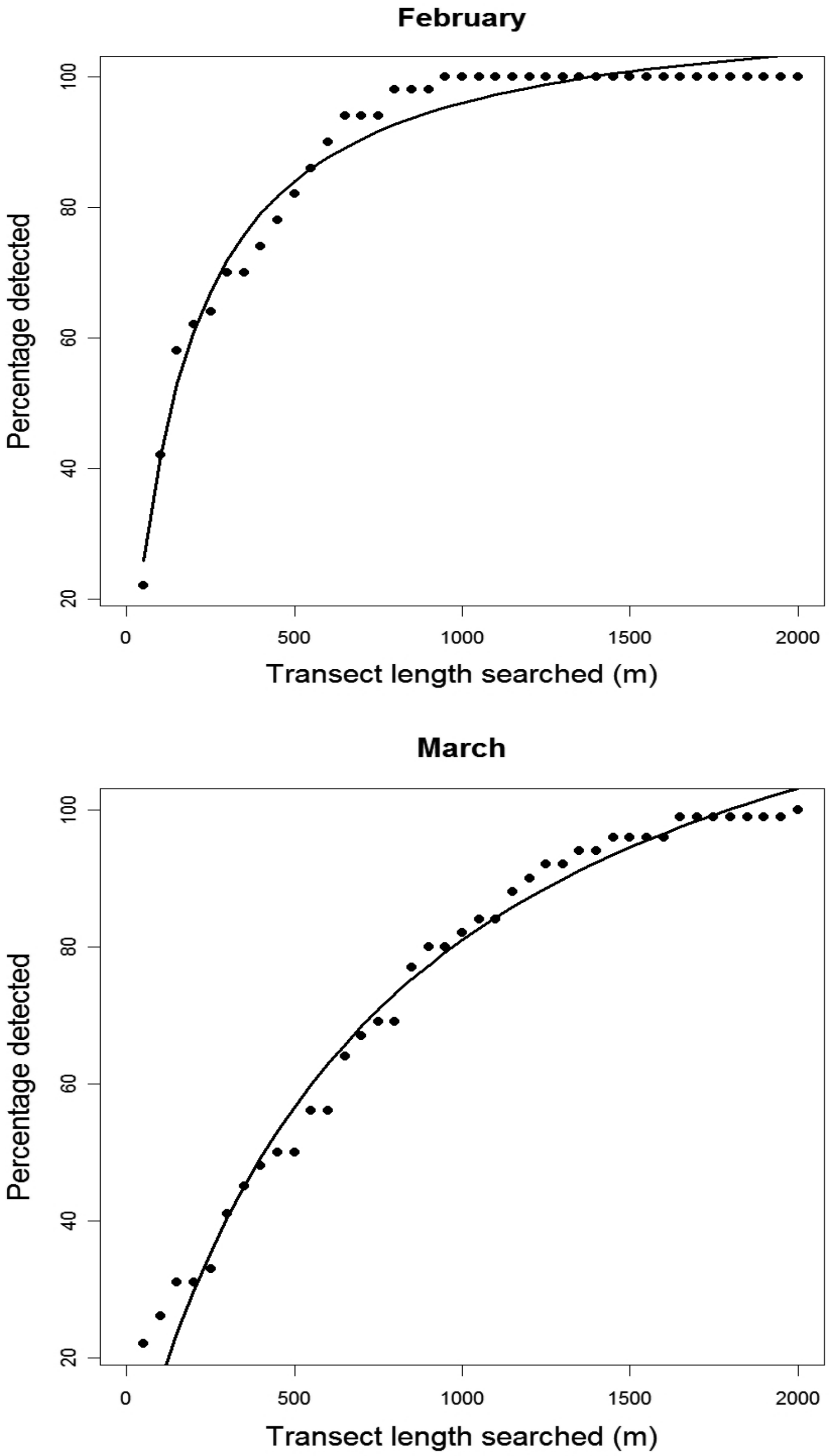

February
Percentage detected
20
40
60
80
100
0
500
1000
1500
2000
Transect length searched (m)
March
Percentage detected
20
40
60
80
100
0
500
1000
1500
2000
Transect length searched (m)

Figure 4c-d.

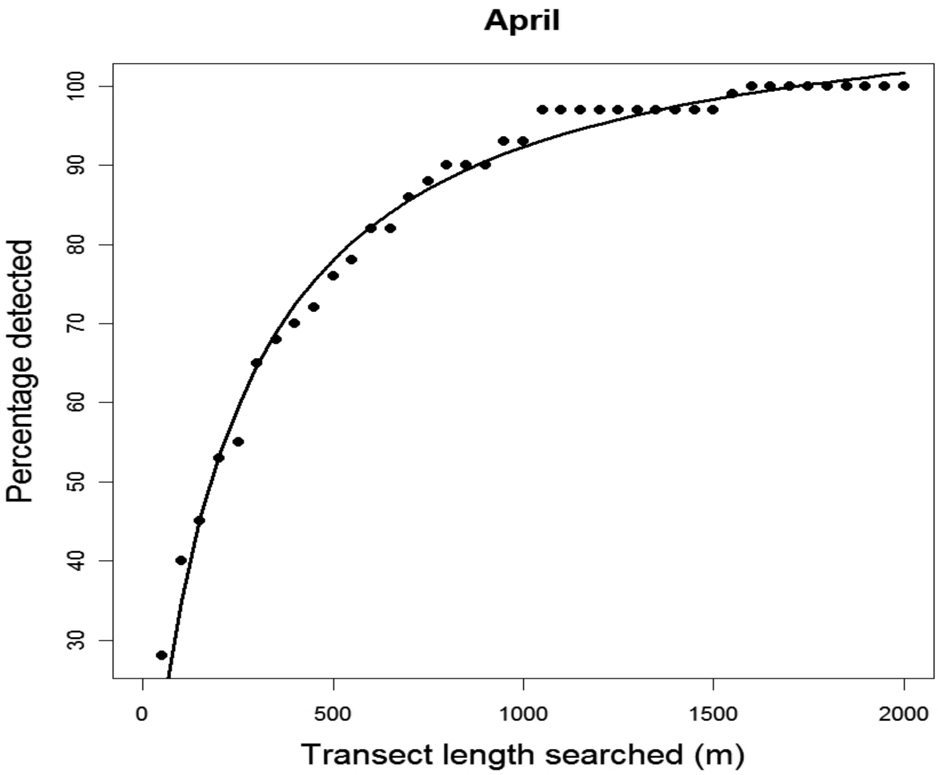

April
Percentage detected
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
Transect length searched (m)

Figure 4e.

RESUMEN

El estudio de la distribución de especies introducidas es uno de los elementos esenciales a abordar en los planes de gestión de estas especies dirigidos a mitigar su impacto sobre la fauna local. En el caso del visón americano, la determinación y el conocimiento de su distribución y de su evolución furuta son unas de las prioridades dentro de la estrategia nacional de conservación del visón europeo en España (02MNAT/8604, 00NAT/E/7299, 00NAT/E/7335, 00NAT/E/7331 2001-2008 European Life Programs; MMA 2006). Dada la dificultad y el gasto económico que representan los muestreos directos, la manera más apropiada de realizar prospecciones es mediante muestreos indirectos (muestreo de rastros). Actualmente, no existe una metodología adecuada para el muestreo indirecto del visón americano, por lo que se utiliza la metodología empleada para los estudios de prospecciones de nutria (transectos lineales de 600 m).

El presente estudio tiene como objetivo verificar la validez de esta metodología para el caso del visón americano, así como examinar los siguientes factores: 1) Patrón general de deposición de rastros; 2) Longitud mínima de transecto; 3) Probabilidad de detección de los rastros del visón americano.

El estudio se realizó a lo largo de 5 km del río Llobregat y a lo largo de 4 km de su afluente la riera Gavarresa. Ambos ríos se dividieron en secciones de 100 m prospectando mensualmente sus respectivas orillas (10 m desde la orilla) en busca de rastros (huellas y excrementos), desde diciembre de 2004 hasta abril de 2005. Dado que algunas secciones resultaron inaccesibles, el análisis se realizó para un total de 40 secciones del río Llobregat y 17 de su afluente la riera Gavarresa.

En el análisis del patrón general de deposición de rastros, se ha calculado el número de secciones positivas (secciones con al menos un rastro) respecto al mes, el río y la orilla de cada río (derecha/izquierda). Asimismo, se han comprobado posibles diferencias entre los meses, empleando un test χ^2; entre los ríos, mediante tabla de contingencia; y entre las orillas, también mediante tabla de contingencia. Para el análisis de longitud mínima del transecto, se midieron mensualmente las distancias entre rastros y se representó su correspondiente distribución. La identificación de la mínima distancia requerida se ha evaluado a través de la representación de las curvas mensuales de frecuencia de distancia acumulada (curva de rarefacción), en las que se representa el porcentaje de rastros detectados (eje vertical) por longitud de transecto prospectado (eje horizontal). Por último, la probabilidad de detección de los rastros se ha analizado empleando el programa PRESENCE, siguiendo la metodología descrita por MacKenzie *et al.* (2002). La probabilidad de detección se ha calculado para transectos de 600 m y 100 m.

Los resultados muestran un media de 23% (SD = 5, n = 5) de secciones positivas de 100 m, con menor porcentaje en los meses de marzo y abril que en el resto (Mann-Whitney U = 0,00, p = 0,10, $n_{\text{dic-feb}} = 3$ y $n_{\text{mar-abr}} = 2$) (Figura 2). No se encuentran diferencias significativas entre ríos (χ^2 = 10, df = 9, p = 0,27, n = 10) (Llobregat: χ^2 = 10, df = 6, p = 0,13, n = 10; Gavarresa: χ^2 = 10, df = 9, p = 0,35, n = 10). En relación a las distancias mínimas, las distancias entre rastros encontrados son: diciembre = 339 m; enero = 378 m; febrero = 380 m; marzo = 656 m; abril = 427 m (Figura 3); en los transectos de 600 m se detecta la presencia de visón entre el 72% y el 90% de los casos, excepto para el caso de marzo, en que se reduce al 56% (Figura 4). La probabilidad de detección media resulta de 75% en transectos de 600 m de diciembre a febrero, y de 65% de diciembre a abril. La probabilidad desciende a 63% y 36%, respectivamente, en el caso de transectos de 100 m.

Los resultados muestran que la metodología de prospección de nutria es aplicable al visón americano aunque sólo en ciertas épocas del año, dentro de los meses estudiados. Sin embargo, para evitar errores en la detección de la población, se ha de tener en cuenta que el tamaño territorial del visón americano es menor. Asimismo, existe una estacionalidad anual que se ha de valorar a la hora de diseñar la metodología de prospección de la especie. Esta estacionalidad también se observó en otros estudios, en los que se ha indicado una disminución de la probabilidad de detección del visón americano tras la época de apareamiento (e.g. Robinson, 1987; Bonesi y Macdonald, 2004; Harrington, Harrington y Macdonald, enviado). Se ha barajado la idea de que esta época, que en los países del norte comienza en abril (Dunstone, 1993), podría adelantarse a marzo en latitudes más al sur. Sin embargo, hasta el momento no disponemos de datos suficientes como para corroborar esta afirmación. En relación a la probabilidad de detección, ésta resultó mayor que la encontrada por Bonesi, Strachan y Macdonald (2006) en Inglaterra, probablemente debido a la diferencia de la densidad poblacional en cada zona (1,16 y 0,3 visones/km respectivamente).

El presente estudio concluye que la metodología de transectos de 600 m usada en las prospecciones estándar de nutria se adecúa para prospectar visones en áreas con elevada densidad poblacional y durante la época pre-reproductora, mientras que la longitud de los transectos debería aumentar a 900 m durante la época de gestación y lactancia (marzo-abril).

RESULTADOS

ADAPTACIONES MORFOLÓGICAS DE UNA POBLACIÓN INVASORA DE VISÓN AMERICANO

La Tabla 1 muestra los resultados de los parámetros morfológicos estudiados.

Tabla 1. Media, desviación estándar (SD) e intervalo de valores para el peso (BW), longitud total (BL), longitud de la cola (TL), longitud del pie posterior (HL) y longitud de la oreja (EL). Peso expresado en g; longitudes en mm; n: número de visones medidos.

	Subadulto		Adulto	
Variable	Macho	Hembra	Macho	Hembra
BW				
Media	965,18	593,87	1133,06	767,60
Intervalo	767-1233	460-743	830-1554	526-1474
SD	133,68	88,55	163,00	290,30
BL				
Media	415,29	351,69	435,19	386,70
Intervalo	390-440	250-392	370-500	350-460
SD	13,58	33,99	28,26	36,67
TL				
Media	206,65	180,88	210,83	181,60
Intervalo	162-230	150-210	120-241	150-205
SD	22,23	13,70	21,77	15,82
HL				
Media	65,76	59,13	69,36	63,10
Intervalo	50-74	45-75	45-91	57-80
SD	15,47	7,99	10,27	7,02
EL				
Media	22,12	19,88	23,92	20,90
Intervalo	19-28	14-28	16-30	19-30
SD	2,15	3,67	3,28	3,25

Morfológicamente la población presenta dimorfismo sexual para todos los parámetros estudiados: peso (BW), longitud total (BL), longitud del pie posterior (HL) y longitud de la oreja (EL) excepto para la longitud de la cola (TL) (Tabla 2).

Tabla 2. Resultados del modelo lineal general mixto (GLMM) para el análisis de los parámetros morfológicos: peso (BW), longitud total (BL), longitud de la cola (TL), longitud del pie posterior (HL) y longitud de la oreja (EL). d.f.: grados de libertad.

Modelo-efecto fijo	F	d.f.	P
BW			
Año	1,60	2	0,217
Sexo	23,41	1	<0,0001
Edad	9,54	1	0,004
Interacción sexo-edad	3,32	1	0,078
BL			
Año	2,48	2	0,099
Sexo	33,31	1	<0,0001
Edad	9,72	1	0,041
Interacción sexo-edad	2,61	1	0,116
TL			
Año	1,02	2	0,365
Sexo	27,54	1	<0,001
Edad	0,56	1	0,457
Interacción sexo-edad	0,11	1	0,745
HL			
Año	1,75	2	0,181
Sexo	11,02	1	0,001
Edad	2,69	1	0,105
Interacción sexo-edad	0,25	1	0,618
EL			
Año	1,43	2	0,260
Sexo	16,44	1	<0,0001
Edad	1,14	1	0,288
Interacción sexo-edad	0,05	1	0,818

El grado medio de dimorfismo sexual es de 1,20 (SD = 0,22, n = 6), con un mínimo de 1,03 para la longitud de la cola y de 1,63 para el peso. Para todos los parámetros estudiados los machos son mayores que las hembras, pudiéndose establecer la siguiente secuencia, de mayor a menor: machos adultos > machos subadultos > hembras adultas > hembras subadultas. De hecho, el sexo resulta ser un factor significativo para todas las variables morfológicas estudiadas. La edad es significativa en el caso del peso y la longitud corporal pero no en el resto de variables.

HÁBITOS ALIMENTICIOS DEL VISÓN AMERICANO, LA NUTRIA Y LA JINETA EN SIMPATRÍA

La población de visón americano de la zona de estudio presenta como base de su dieta alimenticia, en términos de abundancia de presa, el consumo del cangrejo americano, *Procambarus clarkii*, tanto en primavera-verano como en otoño-invierno ($\chi^2 = 5,19$, df = 3, p = 0,13) (Figura 1). Sin embargo, en términos de biomasa la dieta viene complementada con micromamíferos, peces y aves que, junto al cangrejo americano, constituyen la base energética de su dieta. La composición de la dieta muestra variaciones estacionales a lo largo del año ($\chi^2 = 40,83$, df = 3, $p < 0,001$) (Figura 2). La composición de la dieta del visón coincide con la de la jineta dentro del bosque de ribera. El cangrejo americano es también el componente principal, en términos de frecuencia relativa de ocurrencia, de este carnívoro, si bien, y como en el caso del visón, en términos de biomasa también se observa que está complementada con el consumo de micromamíferos, peces y aves (Figuras 1 y 2). En el caso de la jineta tanto la frecuencia relativa de ocurrencia de presas como la biomasa consumida presentan variaciones estacionales ($\chi^2 = 13,82$, df = 3, $p < 0,001$ y $\chi^2 = 61,44$, df = 3, $p < 0,001$, frecuencia relativa de ocurrencia y biomasa respectivamente). En cambio, la nutria presenta un espectro alimentario de especialista, alimentándose casi exclusivamente de peces tanto en primavera-verano como en otoño-invierno ($\chi^2 = 4{,}88$, df = 1, p = 0,03) (Figuras 1 y 2). Este carácter de especialista frente al comportamiento trófico más generalista del visón y la jineta se observa reflejado en la amplitud de nicho trófico de cada especie (Tabla 3). En consecuencia, el solapamiento de nicho entre la jineta y el visón americano es más elevado que ente cualquiera de éstos y la nutria.

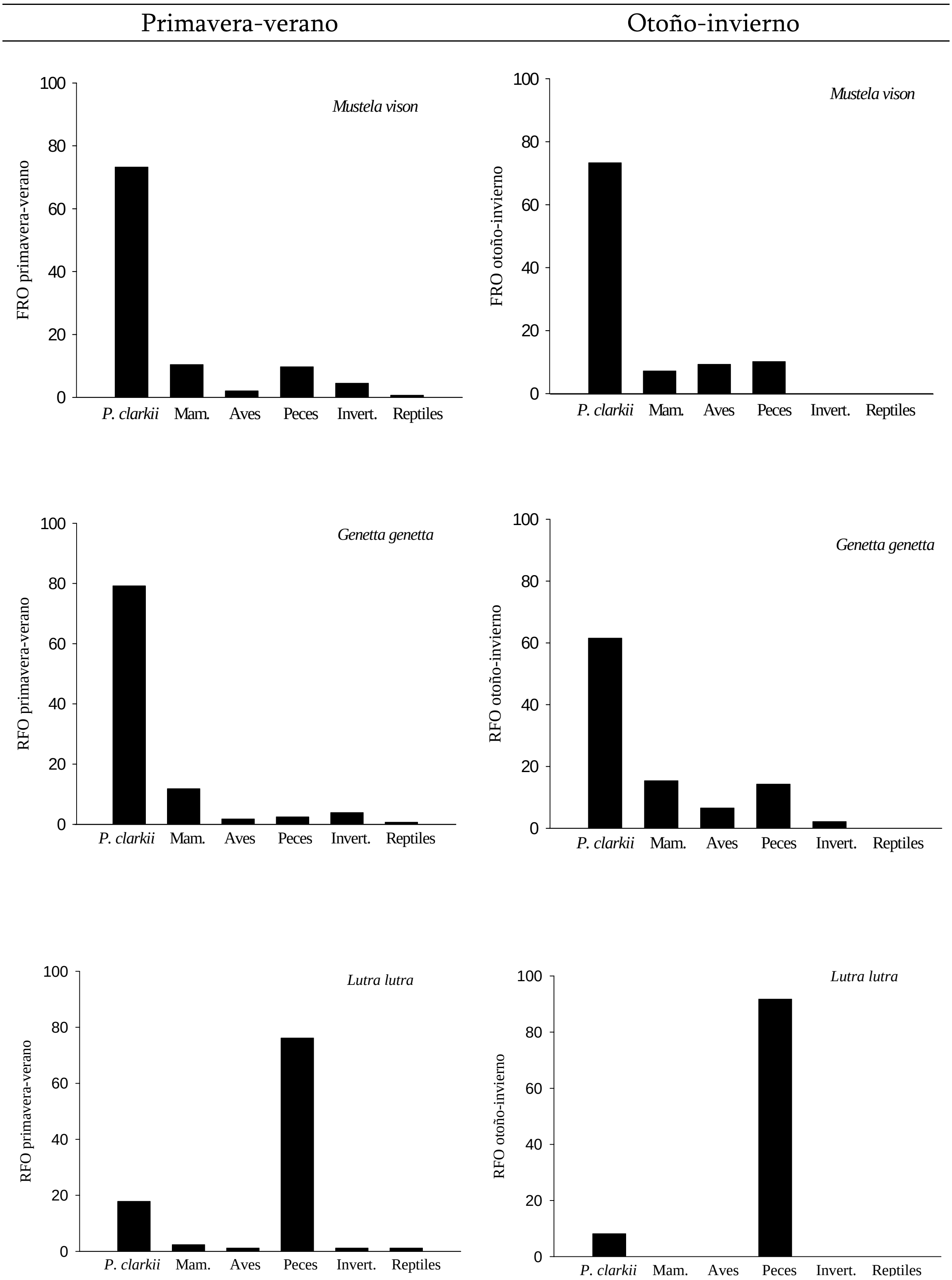


Figura 1. Comparación de la dieta del visón americano, la jineta y la nutria en primavera-verano y otoño-invierno en Cataluña, España. Se muestran seis categorías de presas expresadas como frecuencia relativa de ocurrencia (RFO).

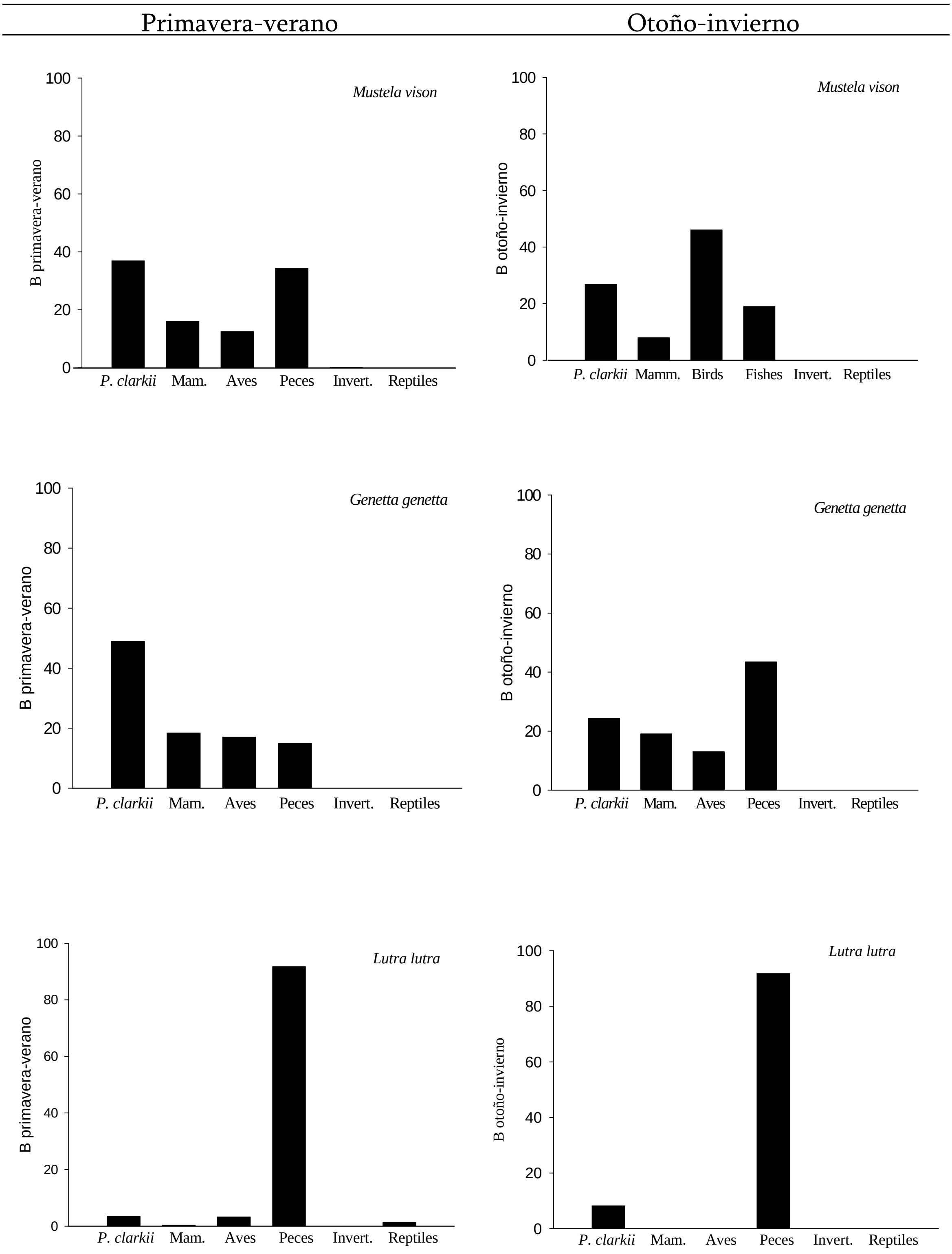


Figura 2. Comparación de la dieta del visón americano, la jineta y la nutria en primavera-verano y otoño-invierno en Cataluña, España. Se muestran seis categorías de presas expresadas como frecuencia relativa de ocurrencia (RFO).

Tabla 3. Amplitud de nicho (B) y solapamiento de nicho (α) del visón americano, la jineta y la nutria en primavera-verano y otoño-invierno en Cataluña. En los cálculos se incluyen todos los ítems de presas en los cálculos.

		Primavera-verano			Otoño-invierno		
		M.	*G.genetta*	*L. lutra*	*M. vison*	*G.genetta*	*L. lutra*
B		0,16	0,11	0,13	0,16	0,27	0,03
α	*M. vison*	-	0,37	0,17	-	0,33	0,12
	G.genetta	-	-	0,14	-	-	0,15

PATRONES TERRITORIALES Y SELECCIÓN DE HÁBITAT DEL VISÓN AMERICANO

En relación a los tamaños territoriales, los ejemplares estudiados presentan un área vital de 0,82 ± 017 km para los machos adultos residentes (n = 7), de 0,61 ± 0,14 km para las hembras adultas residentes (n = 3), de 0,82 ± 0,17 km para los machos subadultos residentes (n = 3), y de 0,43 ± 0,01 km para las hembras subadultas residentes (n = 2). En el caso del área núcleo los resultados son de 0,21 ± 0,09 km para los machos adultos, de 0,21 ± 0,14 km para las hembras adultas, de 0,20 ± 0,04 km para los machos subadultos, y de 0,43 ± 0,01 km para las hembras subadultas (Tabla 5 y Figura 5).

El tamaño territorial del área vital está influido por el peso del animal (F = 8,44, df = 1, P = 0,17) pero no por la edad o el sexo. Asimismo, el río como factor ambiental resulta ser también una variable significativa en relación al tamaño del área vital (F = 5,94, df = 1, P = 0,02). Ningún factor resulta significativo en el tamaño del área núcleo.

En relación a la selección de hábitat, se observa un efecto positivo de la abundancia de vegetación helofítica respecto a la presencia del visón (número de radiolocalizaciones), y un efecto negativo de la presencia de actividad humana. Así, los ejemplares estudiados seleccionan las zonas de mayor cobertura helofítica y menor presencia de actividad humana (F = 3,45, df = 5, P = 0,007 y F = 3,18, df = 2, P = 0,047, respectivamente).

Tabla 5. Áreas vitales, áreas núcleo y solapamiento de áreas vitales (%) de los individuos radioseguidos durante los años 2003, 2004 y 2005. SA: subadulto, A: adulto; r: residente, t: transeúnte.

Individuo	Edad	Estado	Área vital (km)	Área núcleo (km)	Solapamiento (%)
2003					
Macho 1	SA	r	1,01	0,19	67 % (F1) 58 % (M3)
Macho 2	A	r	1,01	0,19	-
Macho 3	A	t	2,56	0,23	16 % (M1) 14 % (F1) 19 % (M4)
Macho 4	A	r	0,71	0,36	68 % (M3)
Hembra 1	A	r	0,77	0,37	87 % (M1) 46 % (M3)
2004					
Macho 5	A	r	0,44	0,13	-
Macho 6	SA	t	2,61	0,31	14 % (M7) 16 % (M8) 16 % (M9) 19 % (M10) 5 % (F3) 8 % (M11)
Macho 7	A	r	1,86	0,27	20 % (M6) 33 % (M11)
Macho 8	SA	r	0,77	0,17	59 % (M10) 53 % (M6)
Macho 9	A	r	0,71	0,15	57 % (M6) 9 % (M11)
Macho 10	A	r	0,65	0,10	70 % (M8) 75 % (M6)
Macho 11	A	t	1,60	0,11	39 % (M7) 4 % (M9) 12 % (F2) 13 % (M6)
Hembra 2	A	r	0,52	0,09	37 % (M11)
Hembra 3	SA	r	0,44	0,14	27% (M6)
2005					
Macho 12	SA	r	0,68	0,24	-
Macho 13	A	r	0,87	0,29	47 % (F5)
Hembra 4	A	r	0,53	0,19	-
Hembra 5	SA	r	0,42	0,15	100 %(M13)

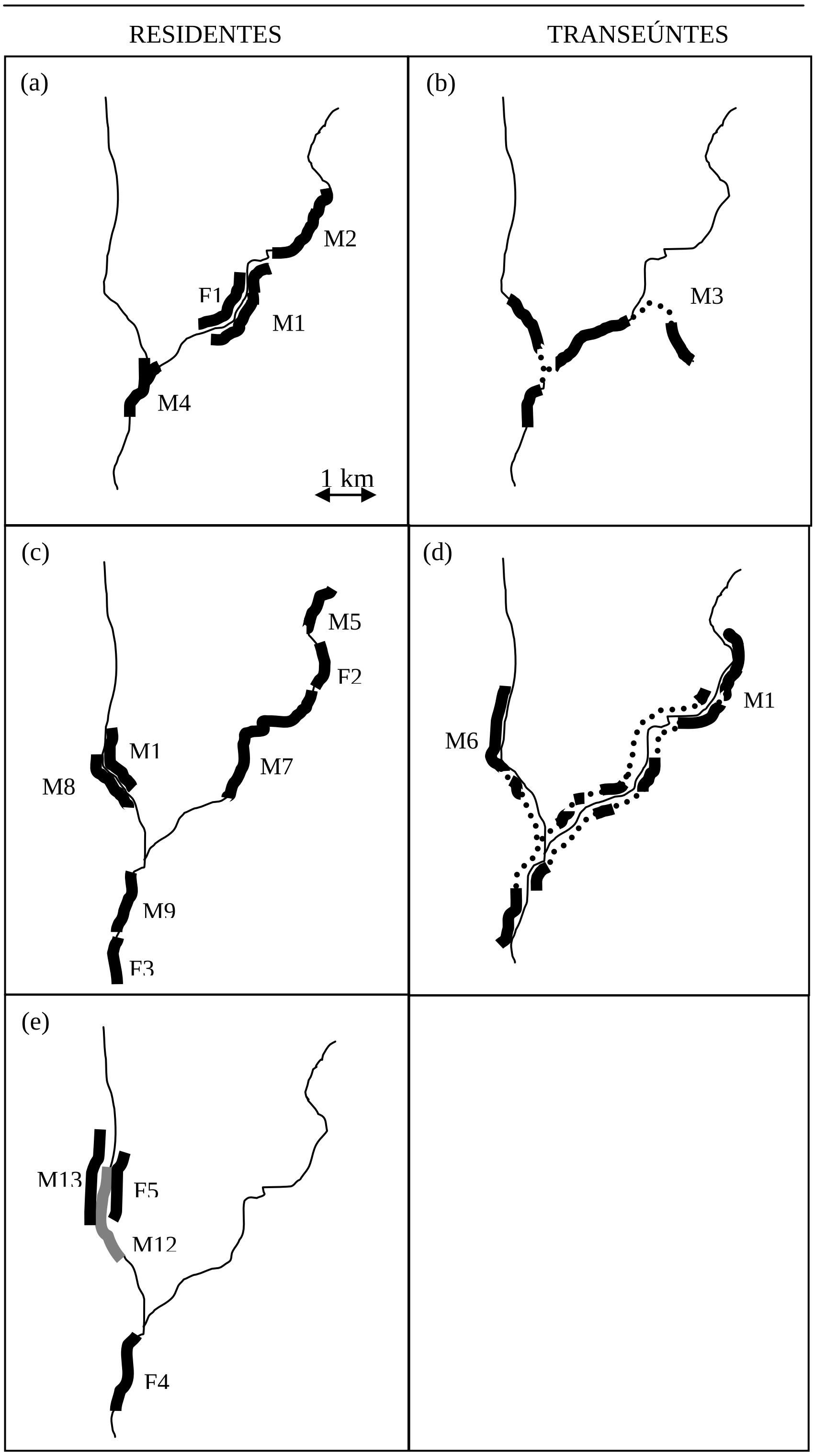


Figura 5. Áreas vitales de residentes y transeúntes durante los años 2003 (a, b); 2004 (c, d); y 2005 (e). Las líneas discontinuas indican zonas en las que no se radiolocalizaron los transeúntes pero por donde se deduce que estuvieron.

PATRÓN DE ACTIVIDAD DEL VISÓN AMERICANO

Los ejemplares estudiados mediante radioseguimiento presentan los siguientes porcentajes de actividad a lo largo del día: comportamiento de actividad local (actividad sin desplazamiento) 27,6%, actividad de locomoción (actividad con desplazamiento) 13,9% e inactividad 58,5%. La actividad diurna se divide en 29,4 % de actividad local y 13,3 % de actividad con locomoción. La actividad nocturna, está representada por 5.4 % de actividad local y 20,3 % de actividad con desplazamiento (Figura 3).

Ninguna variable es significativa para la actividad total (actividad local más actividad de locomoción) *versus* inactividad. Sin embargo, la edad y el sexo como factores biológicos, y la precipitación como efecto ambiental son significativos para la actividad de locomoción (Tabla 4). Es importante resaltar que el ritmo circadiano no parece que afecte a la actividad ya sea total o de desplazamiento aunque es cierto que presentaron ligeramente un mayor porcentaje de locomoción durante las horas de oscuridad (Figura 4).

Los resultados relacionados con la actividad proceden de los datos obtenidos con emisores provistos de sensor de actividad, ya que los datos obtenidos con emisores sin sensor subestiman la actividad total ($F = 6{,}14$, $p = 0{,}013$) (Tabla 4). Debido a ésto, en el presente estudio se han utilizado solamente los datos procedentes de los sensores que aportan información precisa sobre la el comportamiento general de actividad del animal (inactivo, local o locomoción).

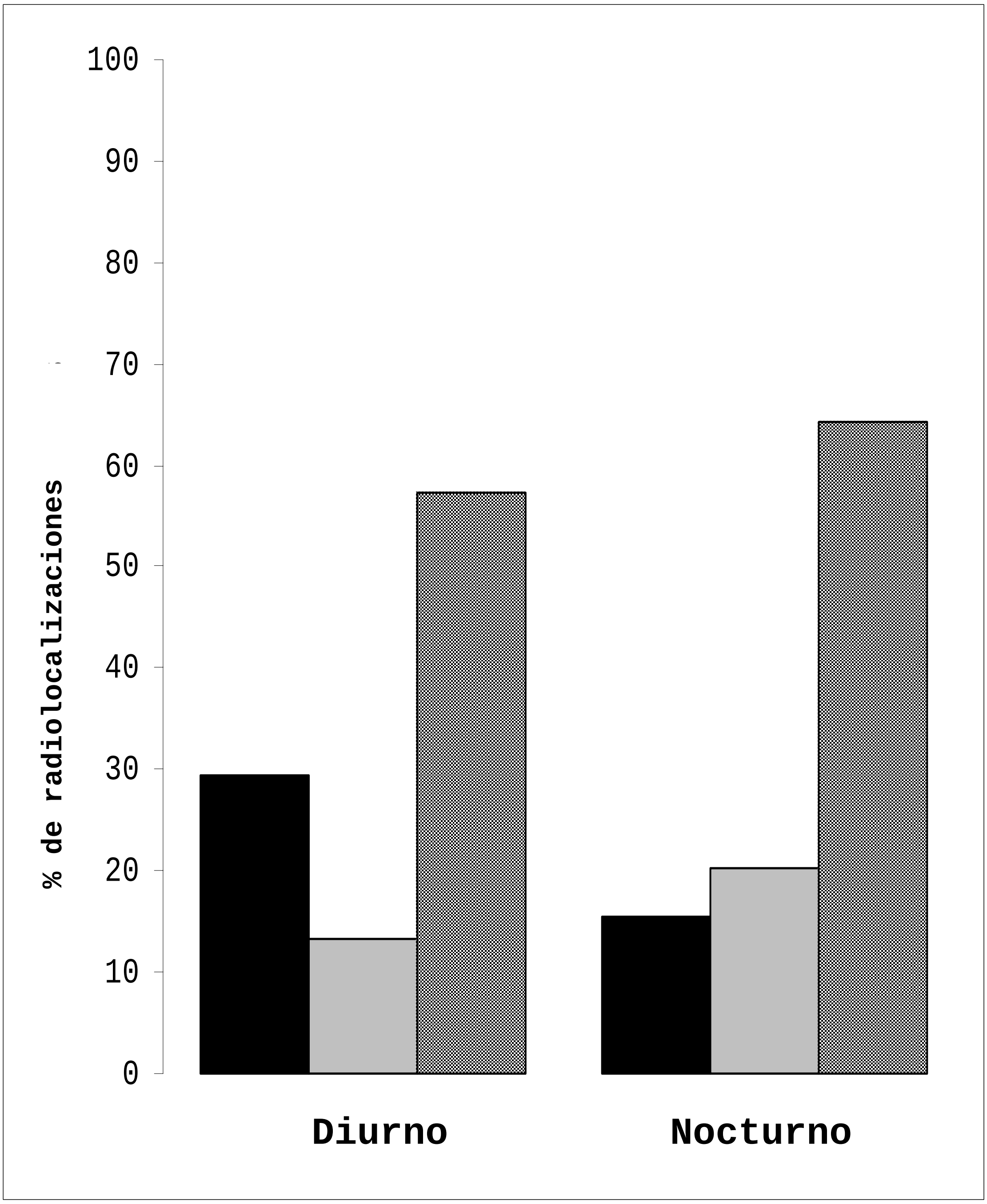


Figura 3. Actividad local sin desplazamiento, actividad de desplazamiento e inactividad nocturna y diurna. Los valores indican porcentajes de radiolocalizaciones.

Tabla 4. Resultados del GLMM para el análisis del sensor (Tipo 1 *vs* Tipo 2), actividad total (actividad local más actividad de locomoción) *vs* inactividad; y actividad de locomoción *vs* actividad local. d.f.: grados de libertad. Los factores significativos aparecen en cursiva.

Modelo-efecto fijo	F	d.f.	P
Análisis de sensor			
Tipo de transmisor	6,14	1	0,013
Sexo	57,19	1	<0,0001
Edad	12,82	1	0,003
Fotoperíodo	1,29	1	0,27
Mes	2,45	1	0,10
Caudal	0,43	1	0,51
Precipitación	30,39	1	<0,0001
Actividad total			
Sexo	2,85	1	0,14
Edad	2,48	1	0,16
Fotoperíodo	4,36	1	0,07
Mes	1,63	3	0,28
Caudal	0,08	1	0,78
Precipitación	1,70	1	0,19
Actividad de locomoción			
Sexo	9,37	1	0,022
Edad	7,23	1	0,036
Fotoperíodo	4,75	1	0,08
Mes	3,01	3	0,16
Caudal	0,10	1	0,75
Precipitación	5,82	1	0,016

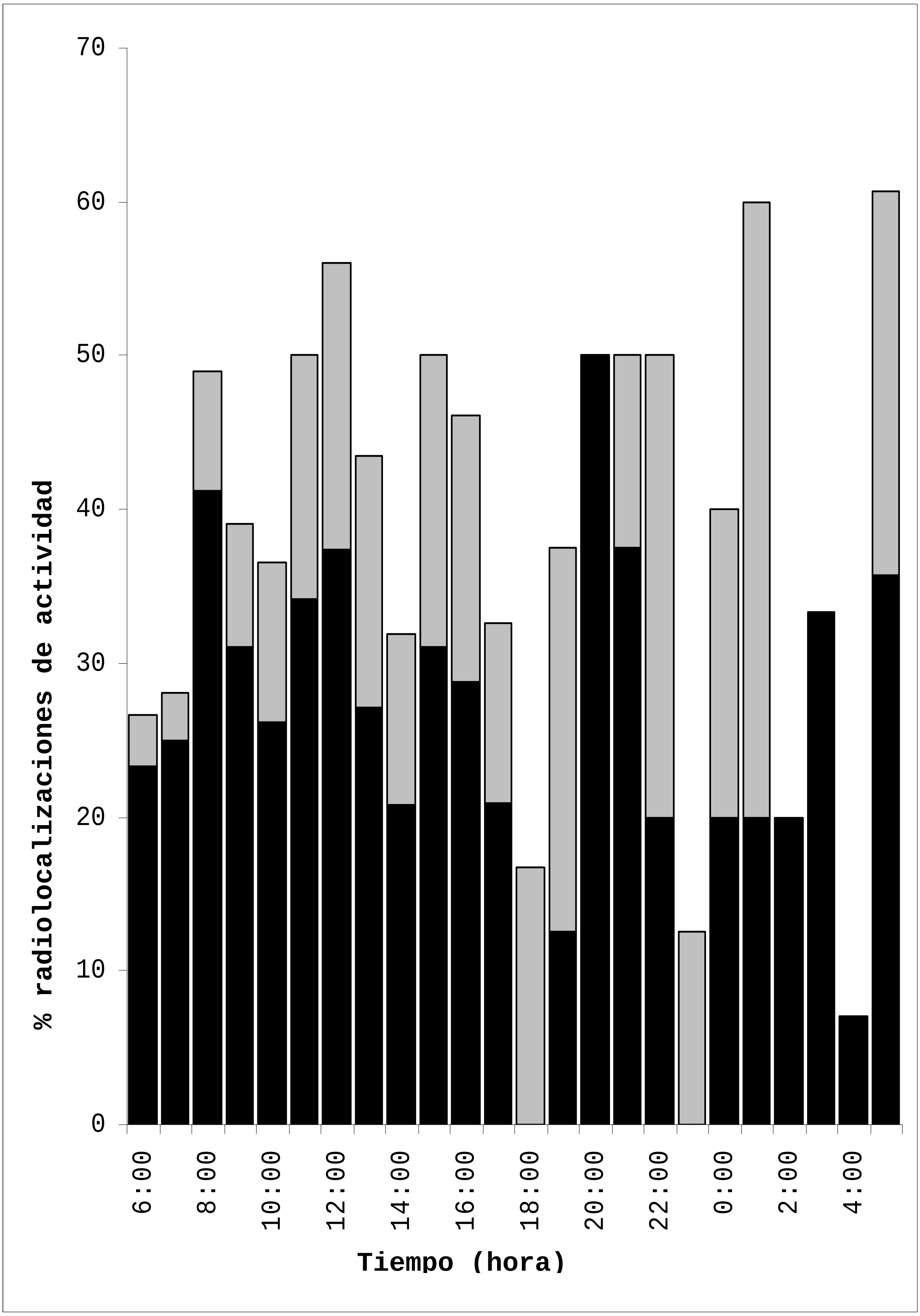


Figura 4. Actividad local, actividad de locomoción e inactividad, diurnas y nocturnas. Los valores indican porcentajes de radiolocalizaciones por hora.

CRECIMIENTO POBLACIONAL Y DISTRIBUCIÓN POTENCIAL DEL VISÓN AMERICANO EN CATALUÑA

La población estudiada presenta una ratio de sexo y edad con una mayor representación de individuos adultos machos, 1: 1,4: 1,6: 2,1 (hembras subadultas, hembras adultas, machos subadultos, machos adultos). Las tasas de crecimiento poblacional anual obtenidas para la población son: λ_{2004} = 0,9, λ_{2005} = 1,06, λ_{2006} = 1 (Figura 6).

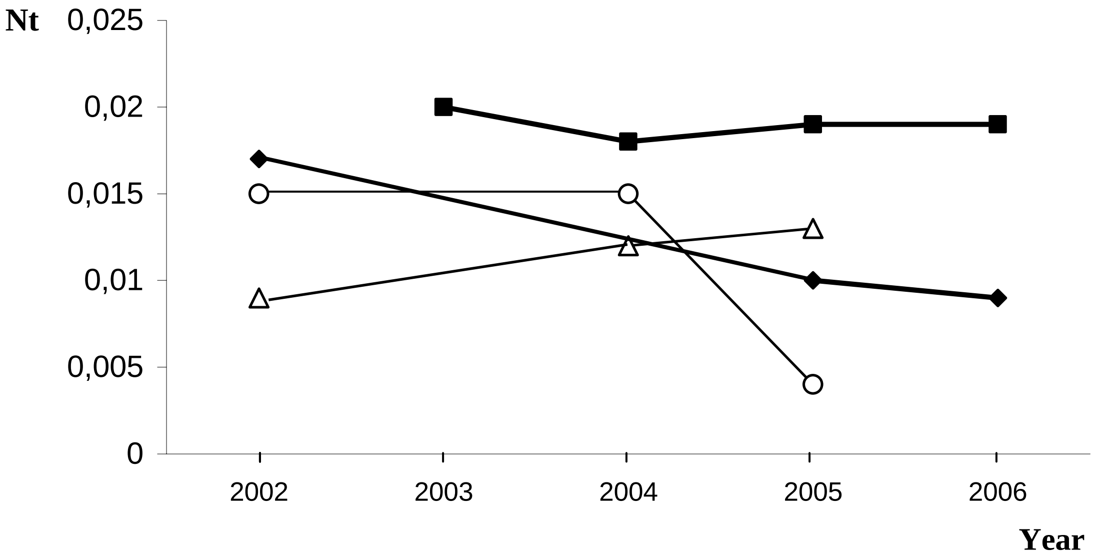


Figura 6. N_t = número de visones capturados/trampas noche para cada uno de los años de muestreo. Círculo = área 1; rombo = área 2; triangulo = área 3; y cuadrado = área control.

Estas tasas de crecimiento son significativamente diferentes respecto a las observadas en tres poblaciones de visón americano en Cataluña sometidas a descaste (H = 8,62, df = 3, p = 0,04), si bien todas ellas se acercaron a la tasa de crecimiento estable (λ = 1). Área 1: λ_{2003} = 0,97, λ_{2004} = 0,97, λ_{2005} = 0,03. Área 2: λ_{2003} = 0,82, λ_{2004} = 0,82, λ_{2005} = 0,82, λ_{2006} = 0,92. Área 3: λ_{2003} = 1,16, λ_{2004} = 1,16, λ_{2005} = 1,15 (Figura 6).

En las figuras 7 y 8 se expone la distribución potencial del visón americano en Cataluña en base a los factores ambientales determinados por el hábitat, la altitud y los cursos de agua presentes.

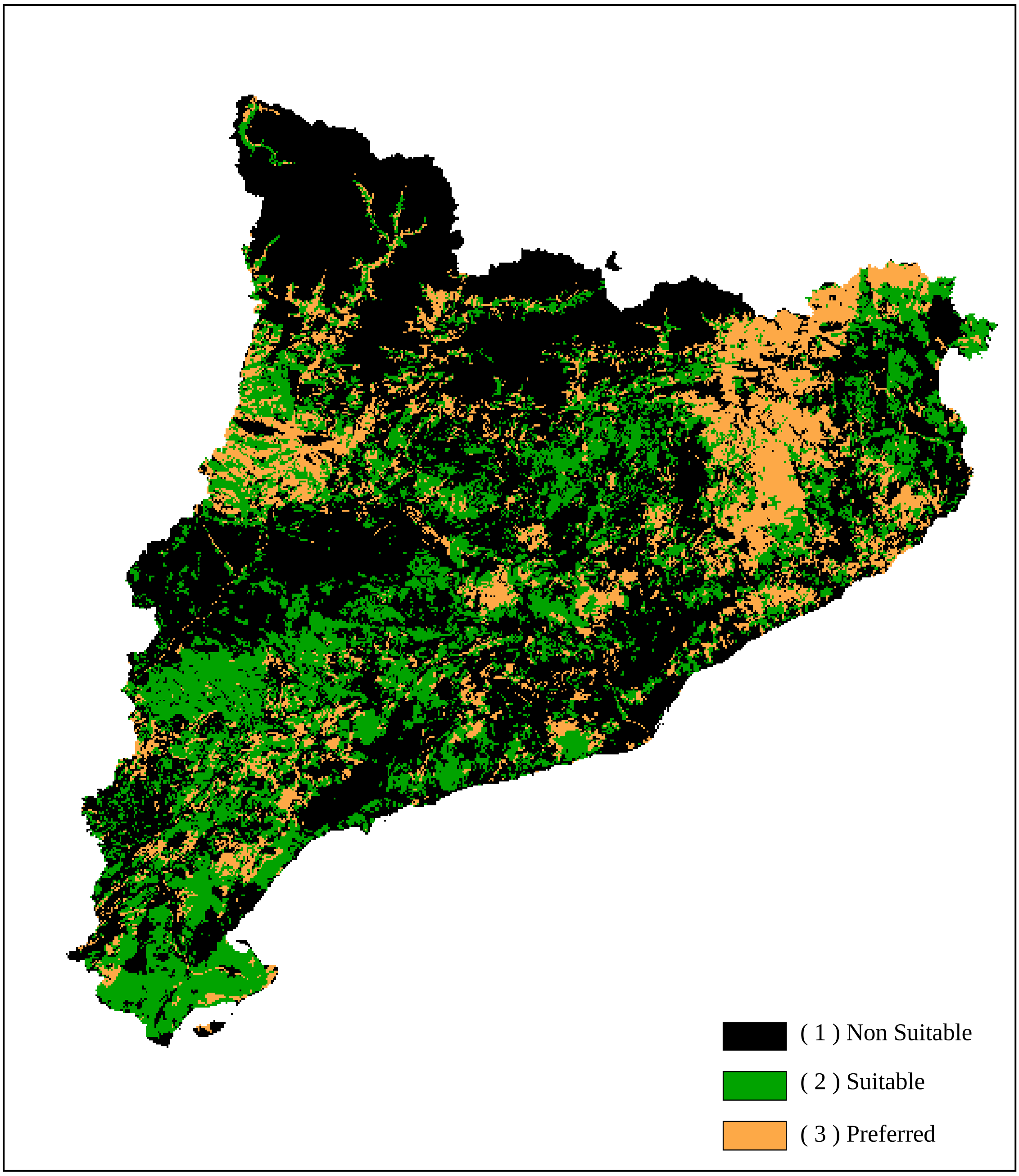


Figura 7. Distribución potencial del visón americano en Cataluña basada en la preferencia del hábitat y el límite de altitud de la especie.

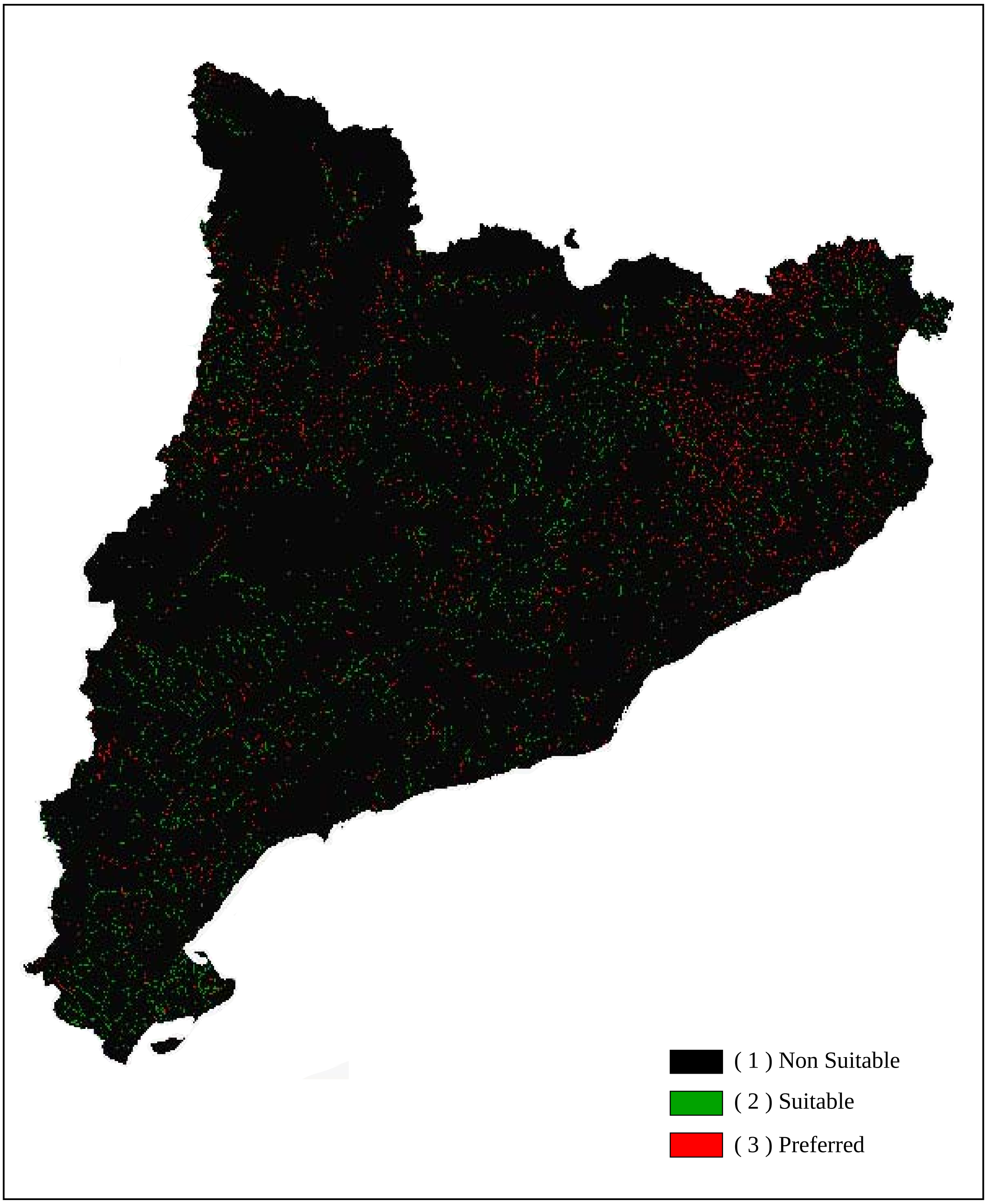


Figura 8. Distribución potencial del visón americano en Cataluña basada en la preferencia del hábitat, el límite de altitud de la especie y la presencia de cursos de agua.

EVALUACIÓN DE LA METODOLOGÍA DE PROSPECCIONES DEL VISÓN AMERICANO

Una media del 23% (SD = 5, n = 5) de las secciones visitadas durante el muestreo de los transectos de 100 m presentó señales de presencia de visón americano, un 16% contenían excrementos y un 7% huellas. Durante los transectos realizados de diciembre a febrero se encontraron un mayor número de señales que durante los realizados en marzo y abril, con una diferencia significativa de 0,10 de probabilidad (Mann-Whitney U = 0,00; p = 0,10; $n_{dec\text{-}feb} = 3$ y $n_{mar\text{-}apr} = 2$). Las distancias entre rastros localizados fueron: diciembre = 339 m; enero = 378 m; febrero = 380 m; marzo = 656 m; abril = 427 m. Cuando los transectos realizados eran de 600 m, el número de secciones con presencia de señales aumentó a 75,8%. Al estudiar la distribución de los rastros en los transectos, se observa que el 60% de las señales mantienen una distancia ente si de 400 m y el 90 % de 900 m (Figura 9), de nuevo con menores distancias en los meses de diciembre a febrero que en marzo y abril.

El análisis de probabilidad muestra que considerando transectos de 600 m, la presencia de visón se detecta en un 60-70% de los casos. La probabilidad de detección empleando transectos de 600 m es de 75 % considerando los meses comprendidos entre diciembre-febrero, mientras que considerando todos los meses desciende a 65%. Al emplear transectos de 100 m estas probabilidades descienden al 63% y 36% respectivamente.

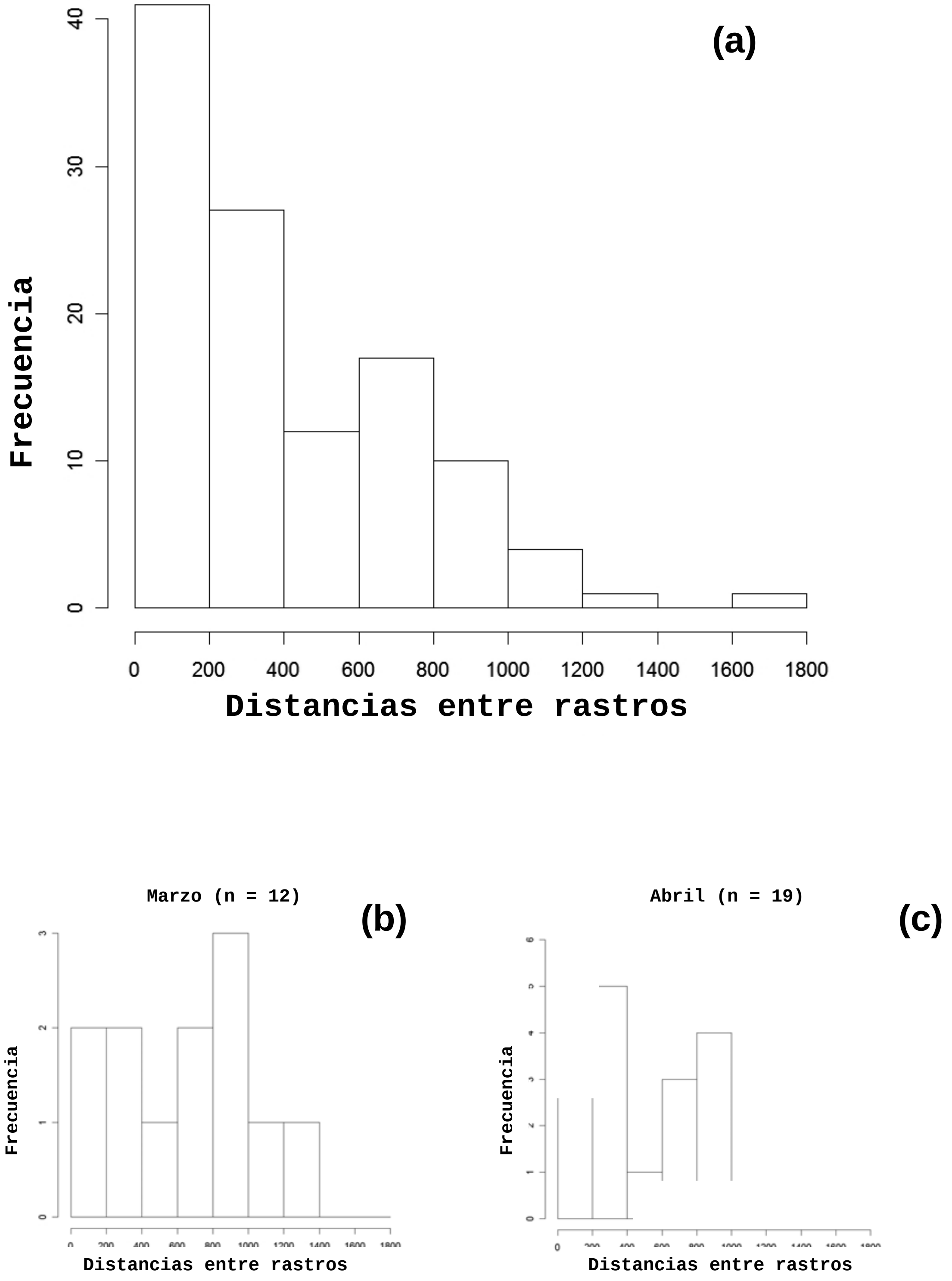


Figura 9. Frecuencia de distribución de distancias entre rastros. El histograma (a) representa los datos de los meses (n=113). Los histogramas (b) y (c) muestran los datos de marzo y abril respectivamente.

DISCUSIÓN

Según los resultados obtenidos y presentados en los diferentes capítulos del presente estudio, se ha podido observar la capacidad de adaptación y de dispersión del visón americano en ambientes mediterráneos como el del área donde se ha realizado el estudio.

Morfológicamente, la población estudiada de visón americano presenta parámetros que difieren de las poblaciones nativas del Norte de América así como de otras poblaciones introducidas en Europa y Rusia (Banfield, 1974; Mitchell, 1961; Farley, 1980; Linscombe *et al.*, 1982; Chanin, 1983; Sidorovich *et al.*, 1999; Sidorovich, 2001; Thom *et al.*, 2004). La elevada variabilidad morfológica observada especialmente entre las poblaciones invasoras se debe por un lado a su procedencia, ya que se seleccionaron tres diferentes subespecies para la cría en cautividad (Dunstone, 1993), y a la adaptación de dichas poblaciones a los nuevos ecosistemas, produciéndose posiblemente uno o varios efectos de "cuello de botella". La población estudiada, no sólo difiere en cuanto a los valores de los parámetros morfológicos, sino que también muestra un menor dimorfismo sexual en el peso y la longitud total que el observado en otras poblaciones invasoras (véase Mitchell, 1961; Banfield, 1974; Sidorovich *et al.*, 1999, 2001 y Thom *et al.*, 2004). Estas diferencias respecto a otras poblaciones cabe pensar que son la consecuencia de la selección de individuos introducidos y de un proceso de adaptación morfológica a las características de los ambientes mediterráneos del área de dispersión actual desde su colonización hace 20 años. El menor dimorfismo sexual, también aparente en los subadultos, se explica por un posible efecto "cuello de botella" producido durante la introducción de la especie por las empresas peleteras, y durante sus escapes tanto masivos como esporádicos (efecto fundador). En segundo lugar, el dimorfismo sexual puede verse reducido por una falta de separación de nicho trófico. En general, los mustélidos presentan diferencias sexuales en el tamaño de las presas consumidas (Birks y Dunstone, 1985; Sealander, 1943; Ireland, 1990; Yamaguchi *et al.*, 2003), lo cual se conoce como la hipótesis de repartición de recursos e implica la existencia de un dimorfismo sexual en el tamaño de los individuos (Brown y Lasiewski, 1972; Dayan *et al.*, 1989). Sin embargo, el estudio de la dieta demuestra que la población de visón americano estudiada se alimenta básicamente de presas pequeñas (mayoritariamente cangrejo de río americano) y no se encuentran diferencias remarcables entre las muestras obtenidas en los territorios de hembras y de machos (observación personal). No existe, por lo tanto, una separación del nicho trófico lo cual reduce la necesidad de que existan machos de tamaño marcadamente superior al de las hembras.

El hecho de que la población estudiada de visón americano se alimente principalmente de las presas anteriormente mencionadas no es arbitrario, sino que refleja el carácter oportunista de la especie en cuanto a la dieta. Varios estudios muestran la alevada variabilidad de la dieta del visón americano en función de la disponibilidad de presas en las diferentes áreas. Por ejemplo, los cangrejos, los peces y los micromamíferos son las presas principales en los ríos Moros y Voltoya del centro de España (Bueno, 1994, 1999; Díez y Lizana, 1999), mientras que su dieta en Gran Bretaña se centra especialmente en el consumo de mamíferos (MacDonald, 2002). Este comportamiento generalista del visón también es corroborado por el resultado de la amplitud de su nicho trófico. Este carácter generalista y oportunista proporciona a la especie una remarcable capacidad de aclimatación trófica a distintos ambientes o situaciones puesto que no presenta la limitación que implica el consumo de un determinado tipo de presas. Un ejemplo de esta capacidad de aclimatación es el simple hecho de su plasticidad estacional, cambiando su consumo de presas en función de su abundancia estacional como ha sido ya observado por otros autores (Sidorovich, 1992, 2000). En el caso de la población estudiada, y en términos de frecuencia de ocurrencia, la dieta del visón americano se basa especialmente en el consumo del cangrejo de río americano, *Procambarus clarkii*. Esta presa, a pesar de ser pequeña y presentar un bajo coeficiente de digestibilidad (Ruiz-Olmo *et al.*, 1998), tiene la ventaja de ser muy abundante en el área de estudio, llegando incluso a alcanzar biomasas que superan las de los peces (datos del Departament de Medi Ambient i Habitatge, Generalitat de Catalunya). Además, es un recurso con una disponibilidad constante a lo largo del año y de fácil captura. Ante estas ventajas, el visón americano ha encontrado en el cangrejo de río un recurso disponible en el que basar su dieta y el cual probablemente le ha facilitado su rápida aclimatación a su nueva área de distribución, como se pone de manifiesto en el área de estudio. De hecho, a pesar de la poca digestibilidad del cangrejo de río y el poco contenido de biomasa aprovechable de los individuos, es un recurso energético suficiente para el mantenimiento de la población estudiada de visón americano, cuyos requerimientos nutricionales son complementados en términos de biomasa por aves, peces y micromamíferos. Esta afirmación se basa en dos aspectos: en primer lugar, el estudio morfológico de la especie en el área de estudio demuestra que los individuos capturados presentan una buena condición física, sin deficiencias o menor peso y tamaño al esperado comparándolo con otras poblaciones en las que la dieta de la especie se basa en presas con mayor aporte energético. En segundo lugar, los estudios de crecimiento poblacional y de los patrones de territorialidad realizados muestran que la población ha alcanzado su capacidad de carga ($\lambda = 1$), con una elevada densidad poblacional (1,16 visones/kilómetro de río) y unos tamaños territoriales medios pequeños (0,82 ± 017 km para los machos adultos residentes (n = 7), 0,61 ± 0,14 km para las hembras adultas residentes (n = 3), 0,82 ± 0,17 km para los machos subadultos residentes (n = 3), y 0,43 ± 0,01 km para las hembras subadultas residentes (n = 2).

Otro resultado observado es la interacción trófica del visón americano con otros depredadores presentes en el área de estudio, concretamente con la nutria y la jineta. Ambas especies comparten nicho espacial con el visón americano, especialmente la nutria dado que los dos son exclusivos del ecosistema fluvial, y por lo tanto se espera cierta interferencia entre ellos que pueda actuar además como un factor control de las poblaciones. En relación a la posible interferencia entre el visón y la nutria, y en base a lo resultados obtenidos, la competencia entre ambas especies podría ser considerada como baja. De hecho, la reciente re-colonización de la nutria en el área de estudio data de hace 5-6 años. Además, el número de excrementos de nutria encontrados comparado con el número de excrementos de visón y jineta, es relativamente bajo. Dado este hecho y bajo el supuesto de que en áreas de abundancia de nutria es relativamente fácil encontrar numerosos excrementos (Bonesi y Macdonald, 2004a), parece ser que la densidad de nutrias en el área es suficientemente baja como para competir con el visón americano quien además mantiene elevadas densidades poblacionales en el área (1,16 visones/km). La escasez de nutria y la abundancia de visón son dos factores que determinan la falta de competencia entre estas especies. Sin embargo, dado que en otras zonas se ha observado la existencia de competencia entre las dos especies cuando ambas son abundantes (Ruiz-Olmo, *et al.*, 1997; Bonesi y Macdonald, 2004b), se espera que un posible aumento de las densidades poblacionales de nutria en el área dé lugar a una mayor competencia con el visón americano, con su correspondiente efecto negativo para la población invasora. En el caso del visón y la jineta, se observa que ambas especies basan su dieta en el consumo de cangrejo de río americano. Sin embargo, el solapamiento de nicho trófico entre ambas resulta bajo (37% en primavera-verano y 33% en otoño-invierno). No obstante cabe recordar que las muestras de jineta se recolectaron exclusivamente en el bosque de ribera. Sin embargo, el territorio de la jineta no es lineal siguiendo el curso del río como en el caso del visón y de la nutria, sino bidimensional extendiéndose mas allá del bosque de ribera (Livet y Roeder, 1987). Por esta razón, las muestras de jineta recolectadas pueden contener presas no capturadas en el bosque de ribera, pudiendo producirse una subestima del solapamiento entre las dietas de la jineta y del visón americano. En cualquier caso, reuniendo toda la información recopilada, tanto la nutria como la jineta no parecen representar en estos momentos unos competidores importantes para la población de visón americano en el área de estudio y posiblemente en el resto de las zonas de Cataluña con similares características.

Retomando el tema de la aclimatación y adaptación de la población, y como se ha comentado anteriormente, los tamaños territoriales de los individuos del área de estudio resultan menores a los esperados según otros estudios consultados. En general, los individuos residentes muestran un porcentaje bajo de solapamiento de áreas vitales y en ningún caso solapamiento de las áreas núcleo. Los estudios de Birks y Linn (1982), de Yamaguchi y Macdonald (2003) en Reino Unido, de Gerell (1970) en Suecia, y de Palazón y Ruiz-Olmo (1995) en España, son ejemplos de poblaciones invasoras con tamaños territoriales mayores a los de la población estudiada. Asimismo, los tamaños territoriales de las poblaciones de visón americano en su área nativa (Norteamérica) son mayores a los observados en las poblaciones invasoras (Stevens *et al.*, 1997). El área de estudio, por lo tanto, no sólo cubre las necesidades metabólicas de los individuos de la población, como se ha demostrado anteriormente, sino que además es suficientemente óptima como para sostener una elevada densidad poblacional y permitir que los individuos mantengan territorios pequeños sin implicar problemas a su supervivencia ni por causas metabólicas ni ecológicas (competencia, falta de refugios). De hecho, el tamaño territorial del visón americano depende de factores biológicos como el peso (Harestad y Bunnel, 1979; Lindstedt *et al.*, 1986; Yamaguchi y Macdonald; 2003) y de factores ambientales, especialmente de la disponibilidad de presas y de refugios (Birks, 1981; Birks y Linn, 1982; Dunstone y Birks, 1983; Halliwell y Macdonal, 1996; Loukmas, 1998; Loukmas y Halbrook, 2001) lo cual se pone de manifiesto en los resultados obtenidos. Los tamaños territoriales observados en el río Llobregat, el mayor de los dos ríos estudiados, y por lo tanto el que más presas disponibles aporta, especialmente peces y cangrejos, resultaron mayores a los observados en su afluente, la riera Gavarresa. En cualquier caso, como se observa en el estudio de la dieta, la disponibilidad de presas no parece ser un problema para la población. Asimismo, la disponibilidad de refugios tampoco parece ser un factor limitante. Pero aún así, la mayor disponibilidad de presas y refugios en el río Llobregat podría explicar la diferencia en el tamaño de los territorios en comparación con la riera Gavarresa. Los individuos radioseguidos mostraron una preferencia por áreas dentro de sus territorios con abundancia de vegetación helofítica y poca presencia de actividad humana; es decir, por áreas con presencia de refugios y escasez de peligros potenciales. Es cierto que la presencia de actividad humana es bastante frecuente en el área, y hay registros de que los visones se han observado cerca de huertos o incluso dentro de algunas de las instalaciones (datos personales). Sin embargo, existe una elevada densidad de vegetación helofítica en el área, expandida a lo largo de las orillas de los ríos formando incluso pequeños enclaves de difícil acceso para los humanos y para animales grandes como pueden ser perros. Esta característica confiere, por lo tanto, una protección ante el peligro de humanos o sus animales domésticos (Palazón, 1998; Zabala *et al.*, 2001). Además, la vegetación helofítica tiene la ventaja de un fácil acceso a la presa más frecuente del visón americano, es decir al cangrejo americano, ya que estos se han observado en la zona de estudio en relativa abundancia cerca de las orillas y entre las raíces de la vegetación helofítica. El único inconveniente que podría implicar el uso de la vegetación helofítica como refugio, es su poca capacidad para funcionar como aislante térmico; si bien en áreas de ambiente mediterráneo como la estudiada, las temperaturas mínimas no descienden tanto como para implicar un problema térmico a los diferentes individuos. Se puede concluir, consecuentemente, que la vegetación helofítica del área proporciona, al visón americano, un refugio adecuado dadas las características ambientales y estructurales del área y las necesidades de la especie.

La importancia de la existencia de refugio suficiente para el visón americano no es banal, ya que se observa que los individuos permanecen inactivos dentro del refugio la mayor parte de su tiempo. Esta observación no se aleja de lo esperado, ya que es un comportamiento previamente observado por Dunstone y Birks (1983). En general, y aunque el ritmo circadiano no muestra ningún patrón claro de comportamiento, los individuos estudiados presentan un bajo porcentaje de radiolocalizaciones con un comportamiento activo de desplazamiento. La mayoría de las radiolocalizaciones de actividad indican o una total inactividad o una actividad local sin desplazamiento, ambas con porcentajes diurnos y nocturnos similares. La verdadera diferencia se observa en el comportamiento activo de locomoción, es decir en la actividad con desplazamiento activo bien con fines de protección del territorio bien en busca de alimento. Este comportamiento activo de locomoción resulta mayoritariamente nocturno, pero en menor porcentaje a lo esperado según los datos subministrados por otros autores (Ireland, 1990; Dunstone, 1993, Palazón y Ruiz-Olmo, 1997; Garin *et al.*, 2002a, 2002b). Sin embargo, una de las características adaptativas de la especie, y de muchos carnívoros, es su capacidad para adaptar sus patrones de actividad al de sus presas (Laundré y Keller, 1981; Zielinski *et al.*, 1983; Ferguson *et al.*, 1988; Gerell, 1969, Bonesi *et al.*, 2000). Se considera que el ciclo de actividad de las presas posiblemente esté afectando o condicionando el comportamiento de actividad de la población de visón americano. Las presas más consumidas en el área de estudio son principalmente cangrejo de río, peces y micromamíferos. Tanto los cangrejos de río como los peces pueden ser capturados tanto de día como de noche, pero los micromamíferos con mayor representación en la dieta del visón (*Mus musculus* y *Apodemos sylvaticus*) presentan hábitos fundamentalmente nocturnos. En definitiva, si lo comentado es realmente el factor causante del menor porcentaje de actividad nocturna, ésto no es sino otra muestra de la capacidad de adaptación de la especie a distintos ambientes. Otros factores que influyen, según se ha puesto de manifiesto, en el comportamiento activo de locomoción de los individuos de la población estudiada son el sexo y la edad. No obstante cabe decir que estos resultados entran dentro de lo esperado ya que los machos suelen ser más activos que las hembras y los subadultos que los adultos (Ireland, 1990; Dunstone, 1993; Palazón y Ruiz-Olmo, 1997; Garin *et al.*, 2002a; Garin *et al.*, 2002b; Revilla y Palomares, 2002). Por último, se observa un efecto negativo de la precipitación sobre el comportamiento activo de la locomoción. Este factor ambiental, es un efecto consecuencia del carácter típico mediterráneo con fuertes y esporádicas lluvias otoñales que pueden disturbar la actividad de los animales.

Esta capacidad de aclimatación, y a largo plazo de adaptación, que manifiesta la especie, supone un cierto peligro en términos de conservación. Las poblaciones de visón americano en Cataluña, en la actualidad (2007) no parecen comprometer la existencia de sus presas potenciales si bien son un foco de peligro para la rata de agua mediterránea, *Arvicola sapidus*; algunas especies de aves acuáticas (Anatidae, Ardeidae: *Ardea spp, Ixobrychus minutus, Egretta ssp, Bubulcus ibis* y Rallidae: *Gallinula chloropus* y *Rallus aquaticus*) especialmente por sus posibles ataques a las puestas de huevos y nidadas; Passeriformes (*Motacilla* spp., *Cinclus cinclus*, etc.); algunas especies de reptiles (Testudinidae: *Emys orbicularis* y *Mauremys caspita,* Ofidios: *Natrix* spp.) y de anfibios (Salamadridae: *Salamandra* sp., *Triturus* spp. y *Calotriton* spp., Ranidae: *Rana* spp.); el cangrejo de río autóctono (*Austropotamobius pallipes*); algunas especies protegidas de peces (*Anguilla anguilla*, *Barbus meridionalis, Phoxinus phoxinus, Squalius cephalus* y *Gasterosteus gymnurus*); y a mamíferos competidores como el turón (*Mustela putorius*). Como se observa en los resultados, la distribución potencial de la especie se extiende prácticamente por todo el territorio catalán con especial preferencia en el noreste, donde también habita la rata de agua y varias especies de aves acuáticas (citadas anteriormente). Esta posible simpatría entre presas y depredador constituye el primer problema de gestión y conservación en relación al control de los posibles efectos de la introducción del visón americano en Cataluña. El segundo problema es el riesgo potencial que existe con la dispersión de las poblaciones hacia el oeste y el sur. La dispersión hacia el sur se considera una vía potencial de la especie para colonizar el río Ebro y expandirse a través de él hacia el noroeste con la posibilidad de que en un fututo entre en contacto, a través de esta vía, con la población española de visón europeo (Palazón *et al.*, 2003). En tal caso, la población de visón europeo quedaría definitivamente rodeada por varias poblaciones de visón americano (Palazón *et al.*, 2003) y la probabilidad de conservación de esta población de visón europeo sería casi nula a medio y largo plazo. De hecho, se han encontrado individuos de visón americano en ríos pertenecientes a la cuenca del río Segre, a unos 150 kilómetros del río Ebro (datos del Departament de Medi Ambient i Habitatge, Generalitat de Catalunya). Ante esta situación, la erradicación y/o control del visón americano se debe considerar como una acción de conservación totalmente necesaria y prioritaria. Desde 1999, en Cataluña se llevan a cabo campañas anuales de trampeo y erradicación de visón americano. Sin embargo, y en base a los resultados obtenidos hasta el momento, estas campañas no han conseguido una reducción apreciable de sus poblaciones. Las poblaciones sometidas a descastes, mantienen una tasa de crecimiento poblacional cercana a la tasa de crecimiento estable, es decir $\lambda = 1$. Este resultado no sólo indica que dichas poblaciones están próximas a su capacidad de carga, sino que además este resultado parece ser consecuencia de la capacidad de recuperación de las poblaciones de visón americano, ante el descaste efectuado. La disminución en su tasa de supervivencia parece verse compensada por un aumento en la tasa de fecundidad de la población, como ya ha sido observado en otras poblaciones (Macdonald *et al.*, 2000). Es decir, el aumento de la mortalidad es compensado por un mayor número de crías. Cabe añadir que la capacidad de supervivencia de estas crías es alta ya que, como se ha comentado, las condiciones alimentarias y las características estructurales del hábitat no son elementos condicionales para la especie. Por lo tanto, el control de la especie, por lo menos con las técnicas empleadas actualmente, no parece que pueda alcanzar la suficiente eficacia como para eliminar a las poblaciones asentadas en los sistemas fluviales estudiados y en los de Cataluña. La completa erradicación de poblaciones invasoras de visón americano se ha logrado en determinadas áreas con características especificas tales como el aislamiento, el pequeño tamaño de las áreas, y la no existencia de granjas peleteras de visón americano en actividad (Moore *et al.*, 2003; Genovesi, 2000). A pesar de estos éxitos locales, la erradicación de las poblaciones parece complicada e impracticable en áreas donde no se dan estas características (Dunstone 1993; Boitani, 2001). Sin embargo, limitar la dispersión de las poblaciones asentadas es una meta factible (Dunstone 1993; Boitani, 2001). El hecho de que las poblaciones estudiadas muestren una capacidad elevada de recuperación ante una disminución de la tasa de supervivencia permite, como se ha comentado anteriormente, mantener las poblaciones dentro de cierto rango de estabilidad. Sin embargo, el aumento de la tasa de mortalidad favorece la dispersión local ya que implica un aumento de territorios vacíos no ocupados por ningún individuo, y por lo tanto a disposición de los nuevos individuos nacidos cada año (Macdonal *et al.*, 2000). Es decir, hay una disminución de la tasa de emigración dado que los subadultos no tendrán la necesidad de dispersarse en busca de nuevos territorios disponibles que estén muy alejados de su zona de nacimiento (Macdonal *et al.*, 2000). Existe una alternativa al control por descaste que es el control de la fecundidad, mediante una disminución de la fecundidad (esterilización) en vez de una disminución de la supervivencia (o aumento de la mortalidad). Sin embargo, este método implica un mayor coste económico y una mayor dificultad para llevarlo a cabo. Mediante la esterilización, las poblaciones se mantendrán constantes ocupando los territorios ya que los individuos esterilizados, en principio, no desaparecen de la población y, por lo tanto, su éxito se basa en limitar la dispersón de la población más que en exterminar la población. Dado que parece que los resultados esperados serían similares en ambos casos, resulta más factible desde el punto de vista económico y en términos prácticos la opción del descaste.

Desde un punto de vista teórico lo ideal sería poder esterilizar a los machos (por ser una especie poligámica) después de una campaña intensa de descaste, para intentar controlar los efectivos poblacionales y reducir así la capacidad expansiva de la especie (Smith, 1994). También desde un punto de vista teórico, se puede asimilar el visón americano a una especie estratega de la "r". En estas especies el reducir los efectivos poblacionales a base de eliminar individuos no es la mejor solución para su control, lo que procede es dificultar los mecanismos de reproducción (eliminar nidos, cambiar la sex-ratio, esterilización, eliminar fuentes de alimento) (Smith, 1994). No obstante, en el caso del visón americano cualquiera de estos métodos es de difícil aplicación dadas las características del hábitat que ocupa y del régimen alimentario que presenta. En el caso de la sex-ratio, aunque en los descastes efectuados ya se suelen capturar más machos que hembras, la diferencia no es suficiente como para tener un efectivo importante de control. Lo ideal para el caso específico del visón americano sería realizar descastes globales masivos (para evitar el efecto de las metapoblaciones), combinados con la esterilización de machos y con la destrucción de refugios. Dada la difícil aplicación de estos métodos, cabe realizar controles mediante descastes continuados atendiendo fundamentalmente a las zonas borde de área para evitar la expansión de la especie. La mayor efectividad del control de las poblaciones de visón americano es limitar su dispersión, por lo cual es importante la identificación de áreas clave y el buen planteamiento de las campañas de descaste. Es aconsejable que el trampeo y el control de las poblaciones sea intenso en los límites de las áreas de distribución de la especie, especialmente en la parte norte en base a los mapas obtenidos, y en el sur por el peligro que supone, en un futuro, para el visón europeo. Dunstone (1993) registró desplazamientos de individuos de visón americano de 10 kilómetros, y Gerell (1970) de hasta 40 kilómetros; por lo tanto, para mayor seguridad se aconseja que las campañas de descaste en los límites de distribución se realicen entre estos valores de distancia en ambas direcciones del límite (hacia dentro y hacia fuera).

El esfuerzo de captura y descaste de las poblaciones ha de ir acompañando con muestreos periódicos de presencia y distribución de la especie (Wittenberg y Cock, 2001). La forma más económica y práctica de prospectar las poblaciones es mediante muestreos indirectos en busca de rastros (huellas y excrementos). Hasta ahora, las prospecciones realizadas en Cataluña para determinar la presencia del visón americano han seguido la metodología empleada en los censos de nutria (datos del Departament de Medi Ambient i Habitatge, Generalitat de Catalunya) en toda Europa ("Otter surveys"), ya que no existe una metodología descrita para el visón. En el estudio se demuestra que la metodología empleada para las prospecciones de nutria (transectos de 600 m) es aplicable a las del visón americano bajo las condiciones en las que se encuentra la población estudiada (densidad poblacional elevada, territorios pequeños, hábitat mediterráneo). Sin embargo, se detectan diferencias estacionales en la probabilidad de detección de rastros y en la proporción de secciones con presencia de rastros siendo ambas mayores en diciembre-febrero que en marzo-abril. Las causas de estos resultados no parecen claras, ya que no se han encontrado causas biológicas ni climatológicas que expliquen los datos de los resultados. Bajo la misma metodología, otros estudios han observado una menor detección de presencia de visón americano tras la época de apareamiento (Robinson, 1987; Bonesi y Macdonald, 2004). Se ha barajado la idea de que esta época, que en los países del norte comienza en abril (Dunstone, 1993), podría adelantarse a marzo en latitudes más al sur. Sin embargo, hasta el momento no se dispone de datos suficientes que permitan corroborar esta afirmación aunque sería conveniente estudiar esta posibilidad. En conclusión, se corrobora que el uso de la metodología de prospección de la nutria es adecuada para el visón americano, con transectos de 600 m, aunque es aconsejable aumentar esta distancia a 900 m o repetir dos o más veces los transectos en meses de marzo-abril.

CONCLUSIONES

1. La población invasora de visón americano está perfectamente aclimatada y adaptada al área de estudio. Su capacidad de aclimatación, y de adaptación, se pone de manifiesto a través de la morfología, la dieta, el tamaño de los territorios que ocupan los diferentes individuos de la población y la actividad circadiana que presentan.

2. Las diferencias morfológicas de la población estudiada respecto a otras poblaciones y el menor dimorfismo sexual se explican por un posible efecto "cuello de botella" y por la falta de separación de nicho trófico como consecuencia de la aclimatación y adaptación de la población al área de introducción donde las presas disponibles son básicamente de pequeño tamaño.

3. Una cualidad esencial para esta capacidad de aclimatación es su carácter generalista y oportunista, el cual le permite depredar sobre las presas disponibles en el medio. La abundancia del cangrejo de río americano posiblemente ha contribuido a esta rápida aclimatación y expansión, aportando la energía suficiente para su supervivencia y reproducción, incluso en territorios con menor extensión de visón americano al esperado.

4. La elevada disponibilidad de presas, permite a los individuos de la población presentar tamaños territoriales menores a lo esperado según los resultados obtenidos en otras poblaciones de la especie. Un menor tamaño territorial implica también una mayor densidad poblacional dado que el área presenta elevada capacidad de carga.

5. El menor porcentaje de actividad nocturna que manifiesta el visón americano en la zona de estudio, respecto a otras poblaciones de la especie puede ser una consecuencia de que la mayoría de sus presas en el área de estudio son fundamentalmente nocturnas.

Desde un punto de vista aplicado y compilando la información obtenida en el presente estudio se aconseja que las campañas de descaste se planifiquen siguiendo las siguientes instrucciones:

6. Para efectuar los descastes las trampas se deben colocar en ambas orillas del río, a una distancia entre sí máxima igual a la media del tamaño del área vital de los individuos de la zona, dado que son los puntos con mayor capturabilidad. En áreas con características similares a la del área de estudio sería una distancia de aproximadamente 200 m.

7. La colocación de las trampas debe priorizar puntos con mayor probabilidad de selección por parte de los individuos; es decir, próxima o entre la vegetación helofítica y evitando puntos con elevada presencia de actividad humana. En áreas sin vegetación helofítica se recomienda que se coloquen en aquellos puntos que puedan ser refugio para el animal.

8. Las trampas se han de colocar durante el día y ser revisadas por la mañana, ya que la mayor actividad de desplazamiento de los individuos y por tanto la mayor probabilidad de captura, es por la noche.

9. Las campañas de control y de descaste se han de realizar por toda la extensión de la población, si bien se aconseja que se centren fundamentalmente en los límites de la distribución de la especie y en áreas claves como parques naturales y áreas de interés especial (en términos de gestión y conservación de áreas de especial interés). En ambos casos, el descaste se ha de realizar ampliando los límites de la zona una distancia entre 10-40 kilómetros.

10. Para la realización de prospecciones con el fin de observar la presencia y distribución del visón americano se puede seguir la metodología empleada para las prospecciones de nutria, con transectos de 600 m, ampliándolos a 900 m en los meses de marzo y abril. Para los meses de mayo-noviembre, en los que no se ha realizado el estudio, se aconseja utilizar los transectos de 900 m, más conservadores, mientras no se realicen estudios concluyentes sobre la prospección de los transectos durante los meses comentados.

BIBLIOGRAFÍA

Akande, M. 1972. The food of feral mink (*Mustela vison*) in Scotland. Journal of Zoology, 167: 475-479.

Aliev, F. y Sandersen, G.C. 1970. The American mink (*Mustela vison* Schreber) in the USSR. Säugetierk. Mitteil., 18: 122-127.

Andersen, J. 1981. Minken (*Mustela vison*) og Minkjagten I danmark 1970/71 og 1972/73 (The mink in Denmark). Danske Vitundersogelser, 34: 1-24.

Aurelich, R.J., Ringern, R.K. y Iwanoto, S. 1973. Reproductive failure and mortality in mink fed of Great Lakes fish. Journal of Reproduction and Fertility Supplement, 19: 365-369.

Aurelich, R.J. y Ringer, R.K. 1977. Current status of PBC toxicity to mink, and effect on their reproduction. Archives of Environmental Contamination and Toxicology, 6: 279-292.

Aurelich, R.J., Bursian, S.J. y Napolitano, A.C. 1990. Subacute toxicity of dietary heptachlor to mink (*Mustela vison*). Archives of Environmental Contamination and Toxicology, 19: 913-916.

Arnold, T.W. y Fritzell, E.K. 1990. Habitat use by male mink in relation to wetland characteristics and avian prey abundances. Canadian Journal of Zoology, 68: 2205-2208.

Banfield, A.W.F. 1974. The mammals of Canada. University Toronto Press. Toronto.

Ben-David, M. 1997. Timing of reproduction in wild mink: the influence of spawning Pacific Salmon. Canadian Journal of Zoology, 75: 376-382.

Birks, J.D.S. 1981. Home range and territorial behaviour of the feral mink (*Mustela vison* Schreber) in Devon. Ph.D. dissertation, Exeter University, Exeter, UK.

Birks, J.D.S. y Linn, I.J. 1982. Studies of the home range of the feral mink (*Mustela vison*). Symposium of the Zoological Society of London, 49: 231-257.

Birks, J.D.S. y Dunstone, N. 1984. A note on prey remains collected from the dens of a coast-living mink population. Journal of Zoology, 203: 279–281.

Birks, J.D.S. y Dunstone, N. 1985. Sex-related differences in the diet of the mink *Mustela vison*. Holartic Ecology, 8: 245-252.

Ben-David, M., Bowyer, R.T. y Faro, J.B. 1995. Niche separation by mink and river otters: coexistence in a marine enviroment. Oikos, 75: 41-48.

Bonesi, L. 1996. Spatial organization and feeding ecology of the American mink (*Mustela vison*) in a coastal habitat. M.Sc. thesis, University of Durham, Durham, UK.

Bonesi, L., Chanin, P. y Macdonald, D. 2004. Competition between Eurasian otter *Lutra lutra* and American mink *Mustela vison* probed by niche shift. Oikos, 106(1): 19-26.

Bonesi L., Dunstone N. y O'Conell M. 2000. Winter selection of habitats within interdital foranging areas by mink. Journal of Zoology, 250: 419-424.

Bonesi, L., Harrington, L.A., Maran, T., Sidorovich V.E., y Macdonald D.W. 2006. Demography of Three Populations of American Mink, *Mustela vison*, in Europe. Mammal Review, 36(1): 98-101

Bonesi, L. y Macdonald, D.W. 2004a. Evaluation of sign surveys as a way to estimate the relative abundance of American mink (*Mustela vison*). Journal of Zoology, 262: 65-72.

Bonesi, L. y Macdonald, D.W. 2004b. Impact of released Eurasian otter on a population of American mink: a test using an experimental approach. Oikos, 106: 9-18.

Bonesi, L y Palazón, S. 2007. The American Mink in Europe: status, impacts, and control. Biological Conservation, 134: 470-483.

Bravo, C. y Bueno, F. 1992. Nuevos datos sobre la distribución del visón americano (*Mustela vison* Schreber) en España Central. Ecología, 6: 161-164.

Brown, J.H. y Lasiewski, R.C. 1972. Metabolism of weasels: the cost of being long and thin. Ecology, 53: 939-943.

Brzezinski, M., Jedrzejewski, W. y Jedrzejewska, B. 1992. Winter home ranges and movements of polecats *Mustela putorius* in Bialowieza Primeval Forest, Poland. Acta Theriologica, 37 (1-2): 181-191.

Bueno, F. 1994. Alimentación del visón Americano (*Mustela vison* Schreber) en el río Voltoya (Ávila, Cuenca del río Duero). Doñana Acta Vertebrata, 21 (1): 5-13.

Bueno, F. y Bravo, C. 1990. Distribución y hábitat del visón americano (*Mustela vison* Schreber) en el Sistema Central. Doñana Acta Vertebrata, 17: 165-171.

Chanin, P.R.F. 1983. Observations on two populations of feral mink *Mustela vison* in Devon. Mammalia, 4: 463-466.

Chanin, P.R.F. y Linn, I. 1980. The diet of the feral mink (*Mustela vison*) in southwest Britain. Journal of Zoology, 192: 205-223.

Dayan, T., Simberloff, D., Tchernov, E. y Yom-Tov, Y. 1989. Inter- and intra-specific character displacement in mustelids. Ecology, 70: 1526-1539.

Delibes, M. 1983. Distribution and ecology of the Spanish Carnivores: a short review. XV Congreso Internacional de Fauna Cinegética y Silvestre, Trujillo, 1981: 359-378.

Delibes, M. y Amores, A. 1978. On the distribution and status of Spanish carnivores. Abstr. II Congr. Theriol. Intl, 146. Brno, CSSR.

Díez, D. y Lizana, M. 1999. Distribución, dieta y competencia trófica del visón americano (*Mustela vison*) y la nutria (*Lutra lutra*) en un río del Sistema Central, río Moros, Segovia. Resúmenes IV Jornadas SECEM, Segovia, 34.

Doadrio, I. 2001. Atlas y libro rojo de los peces continentales de España. Departamento de Biodiversidad y Biología Evolutiva. Museo Nacional de Ciencias naturales, CSIC.

Dunstone, N. 1993. The mink. London: Poyser Natural History.

Dunstone, N. y Birks, J.D.S. 1983. Activity budget and habitat usage by coastal-living American mink (*Mustela vison* Schreber). Acta Zoologica Fennica, 174: 189-191.

Eagle, T.C. y Whitman, J.S. 1987. Mink. En: Novak, M., Baker, J.A., Obbard, M.E., Malloch, B. (eds). Wildfurbearer management and conservation in North America. Ontario Trappers Association, North Bay. Pp 614.

Enders, R.K. 1952. Reproduction in the Mink (*Mustela vison*). Proceedings of the American Philosophical Society, 96: 691-755.

Erlinge, S. 1969. Food habits of the otter (*Lutra lutra*) and the mink (*Mustela vison*) in a trout water in Southern Sweden. Oikos, 20: 1-7.

Erlinge, S. 1972. Interspecific relations between otter (*Lutra lutra*) and mink (*Mustela vison*) in Sweden. Oikos, 23: 327-335.

Ferguson, J.W.H., Galpin, J.S. y De Wet, M.J. 1988: Factors affecting the activity pattern of black-backed jackals. Journal of Zoology, 214: 55-69.

Folch i Guillèn, R. y Franquesa, T. 1984. Els altiplans i conques centrals catalanes. En: Enciclopèdia Catalana, S.A. Vol. 7. Història natural dels Països Catalans. Barcelona. Pp: 275-279.

Garin, I., Zuberogoitia, I., Zabala, J., Aihartza, J., Clevenger, A. y Rallo, A. 2002a. Home range of European mink (*Mustela lutreola*) in Southwestern Europe. Acta Theriologica, 47: 55-62.

Garin, I., Aihartza, J., Zuberogoitia, I. y Zabala, J. 2002b. Activity pattern of European mink (*Mustela lutreola*) in Southwestern Europe. Zeitschrift für Jagdwissenschaft, 48: 102-106.

Gerell, R. 1967. Food selection in relation to habitat in mink (*Mustela vison* Schreber) in Sweden. Oikos, 18: 233-246.

Gerell, R. 1968. Food habits of the mink, *Mustela vison* Schreb., in Sweden. Viltrevy, 5: 120-211.

Gerell, R. 1969. Activity patterns of the mink *Mustela vison* Schreber in southern Sweden. Oikos, 20: 451-460.

Gerell, R. 1970. Home ranges and movements of the mink *Mustela vison* Schreber in southern Sweden. Oikos, 21: 160-173.

Gerell, R. 1971. Populations studies on mink *Mustela vison* in sourthern Sweden. Oikos, 8: 83-109.

Gosàlbez, J. 1987. Insectívors i Rossegadors de Catalunya. Metodologia d'estudi i Catàleg faunístic. Barcelona: Ketres.

Hall, E.R. 1981. The mammals of North America. John Wiley and Sons inc. NY.

Halliwell, E.C. y Macdonald, D.W. 1996. American mink *Mustela vison* in the upper Thames catchment: relationship with selected prey species and den availability. Biological Conservation, 76: 51-56.

Harestad, A.S. y Bunnel, F.L. 1979. Home range and body weight – a reavaluation. Ecology, 60: 389-402.

Humprey, R. y Zinn, S. 1982. Seasonal habitat use by river otters and Everglades mink in Florida. Journal of Wildlife Management, 46: 375-381.

Ireland, M.C. 1990. The behaviour and ecology of the American mink (*Mustela vison* Schreber) in a coastal habitat. PhD. Thesis. Durham University, Durham, UK.

Jenkins, D. y Harper, R.J. 1980. Ecology of otter in northern Scotland. II: Analysis of otter *Lutra lutra* and mink *Mustela vison* faeces from Deeside, N.E. Scotland in 1977-78. Journal of Animal Ecology, 49: 737-754.

Kihlström, J.E., Olsson, M., Jensen, S., Johanson, A., Ahlbom, J. y Bergman, A. 1992. Effects of PCB and different fractions of PCB on the reproduction of the mink (*Mustela vison*). Ambios, 21(8): 563-601.

Laundré, J.W. y Keller, B.L. 1981. Home range use by coyotes in Idaho. Animal Behaviour, 29: 449-461.

Lindstedt, S.L., Miller, B.J. y Buskirk, S.W. 1986. Home range, time and body size in mammals. Ecology, 67: 413-418.

Linn, I. y Birks, J.D.S. 1989. Mink (Mammalia; Carnivora; Mustelidae): correction of a widely quoted error. Mammalian Review, 19: 175-179.

Linscombe, G., Kinler, N. y Aulerich, R.J. 1982. Mink *Mustela vison*. En: Chapman, J.A. y Feldhamer, J.A. (eds.). Wild mammals of Norteamérica: Biology, Management and Fisheries, New Iberia, LA. Pp. 629-643.

Livet, F. y Roeder, J.J. 1987. Encyclopédie des carnivores de France: la genette (*Genetta genetta*, Linnaeus, 1758). Société Française pour l'Étude et la Protection des Mammifères, 17: 1–33.

Lodé, T. 1993. Strateégies d´utilisation de l´espace chez le Putois européen *Mustela putorius* L. dans l´ouest de la France. Review Ecology (Terre Vie), 48: 305-322.

Loukmas, J.J. 1998. Criteria for quantifying mink (*Mustela vison*) habitat quality in great lakes basin. PhD dissertation, Southern Illinois University at carbonade, USA.

Loukmas, J.L. y Halbrook, R.S. 2001. A test of the mink habitat suitability index model for riverine systems. Wildlife Society Bulletin, 29 (3): 821-826.

Llorente, G., Montori, A., Sants, X. y Carretero, M.A. 1995. Atlas dels anfibis i reptils de Catalunya i Andorra. Departamento de Biología Animal (Vertebrados). Universidad de Barcelona. Societat Catalana de Herpeptología.

Macdonald, D.W. 2001. The New Encyclopaedia of Mammals. Oxford: Oxford University Press.

Macdonald, D.W., Tattersall, F.H., Johnson, P.J., Carbone, C., Reynolds, J., Langbein, J., Rushton, S.P. y Shirley, M. 2000. Managing British mammals: case studies from the hunting database. Wildlife Conservation Research Unit. Oxford, UK.

Maizeret, C. 1990. Le vison d'Amérique. En: Société Française pour l'Etude et la Protection des Mammifères (ed.). Encyclopédie des carnivores de France (vol. 13-14). Paris, France. Pp : 21-44.

Mañas, S., Ceña, J.C., Ruiz-Olmo, J., Palazón, S., Domingo, M., Wolfinbarger, J.B. y Bloom, M.E. 2001. Aleutian mink disease parvovirus in wild riparian carnivores in Spain. Journal of Wildlife Diseases, 37: 138-144.

Maran, T. y Henttonen, J. 1995. Why is the European mink, (*Mustela lutreola*) disappearing? A review of the process and hypothesis. Annales Zooogici Fennici, 32: 47-54.

Maran, T. y Robinson, P. 1996. European mink Captive Breeding and Husbandry Protocol. European mink Conservation and Breeding Committee. Tallin Zoo.

Marmi, J. 2004. Sistemàtica molecular, filogeografia i genètica de la conservació de mustèlids i de macacs. Tesis Doctoral. Universitat Pompeu Fabra. Barcelona.

Mason, C.F. y Macdonald, S.M. 1983. Some factors influencing the distribution of mink (*Mustela vison*). Journal of Zoology, 200: 281-283.

McDonald, R.A. 2002. Resource partitioning among British and Irish mustelids. Journal of Animal Ecology, 71: 185-200.

Miranda, R. y Escala, M.C. 2002. Guía de identificación de restos óseos de los Ciprínidos presentes en España. Serie Zoológica 28. Pamplona: Publicaciones de Biología de la Universidad de Navarra.

Mitchell, J.L. 1961. Mink movements and populations on a Montana river. Journal of Wildlife Management, 25: 48-54.

Palazón, S. 1998. Distribución, morfología y ecología del visón europeo (*Mustela lutreola* Linnaeus, 1761) en la Península Ibérica. PhD thesis, Universitat de Barcelona.

Palazón, S. 2006. Control del visón americano (*Mustela vison*) en Catalunya. Generalitat de Catalunya -DMAH.

Palazón, S. y Ruiz-Olmo, J. 1992. Activity and use of space of the female American mink (*Mustela vison*) revealed by radiotracking. Doñana Acta Vertebrata, 2 (1-2): 97-102.

Palazón, S. y Ruiz-Olmo, J. 1995. Tracking of a female American mink (*Mustela vison*, Schreber, 1777) in NE Spain. Doñana Acta Vertebrata, 22 (1-2): 97-102.

Palazón, S. y Ruiz-Olmo, J. 1997. El visón europeo (*Mustela lutreola*) y el visón americano (*Mustela vison*) en España. Ministerio de Medio Ambiente, Organismo Autónomo de Parques Nacionales.

Palazón, S. y Ruiz-Olmo, J. 1998. El visón europeo (*Mustela lutreola*) y el visón americano (*Mustela vison*) en España. ICONA, Madrid.

Palazón, S., Ruiz-Olmo, J., Gosàlbez, J., Gómez-Gayubo, A., Ceña, J.C. y Ceña, A. 2003. Trends in distribution of the European mink (*Mustela lutreola* L., 1761) in Spain: 1950-1999. Mammalia, 67: 473-484.

Palomo, J. y Gisbert, J. 2002. Atlas de los Mamíferos Terrestre de España. Madrid: DGCNA-SECEM-SECEMU.

Previtali, A., Cassini, M.H. y Macdonald, D.W. 1998. Habitat use and diet of the American mink (*Mustela vison*) in Argentinian Patagonia. Journal of Zoology, 246: 482-486.

Rage, J.C. 1974. Batraciens fossiles du quaternaire. Bulletin de la Société linnéenne de Lyon, 43: 276-289.

Revilla, E. y Palomares, F. 2002. Spatial organization, group living and ecological correlates in low-density populations of Eurasian badgers, *Meles meles*. Journal of Animal Ecology, 71: 497-512.

Robinson, I.H. 1987: Olfactory communication and social behaviour in the mink (*Mustela vison*). PhD, University of Aberdeen, Aberdeen, UK.

Ruiz-Olmo, J. 1985. Informe sobre la situació el visó americá (*Mustela vison*) a Catalunya, N.E. de la Península Ibérica. Doñana Acta Vertebrata, 14: 142-145.

Ruiz-Olmo, J. 1987. El visón americano, *Mustela vison* Schreber, 1777 (Mammalia, Mustelidae) en Cataluña, N.E. de la Península Ibérica. Doñana Acta Vertebrata, 14: 142-145.

Ruiz-Olmo, J. y Aguilar, A. 1995. Els grans mamífers de Catalunya i Andorra. Lynx editions.

Ruiz-Olmo, J., Jiménez, J. y Margalida, A. 1998. Capture and consumption of prey of the otter (*Lutra lutra*) in Mediterranean freshwater habitat of the Iberian Peninsula. Galemys, 10: 209-226.

Ruiz-Olmo, J., Palazón, S., Bueno, F., Bravo, C., Munilla, I. y Romero, R. 1997. Distribution, status and colonization of the American mink *Mustela vison* in Spain. Journal of Wildlife Research, 2: 30-36.

Ruiz-Olmo, J., Palazón, S., Bueno, F., Bravo, C., Munilla, J. y Romero, R. 1999. Distribution, status and colonization process of the American mink *Mustela vison* in Spain. Journal of Wildlife Research, 2: 30-36.

Sato, J.J., Hosoda, T., Wolsan, M., Tsuchiya, K., Yamamoto, M. y Susuki, H. 2003. Phylogenetic relationships and divergence time among Mustelids (Mammalia, Carnivora) based on nucleotide sequences of the nuclear interphotoreceptor retinoid binding protein and mitochondrial cytochrome b genes. Zoological Science, 20: 243–264.

Sealander, J.A. 1943. Winter food habits of mink in southern Michigan. Journal of Wildlife Management, 7: 411-417.

Sidorovich, V.E. 1992. Comparative analysis of the diets of European mink (*Mustela luteola*) American mink (*M. vison*) and polecat (*M. putorius*) in Byelorussia. Small Carnivore Conservation, 6: 2-4.

Sidorovich, V.E. 2000. Seasonal variation in the feeding habits of riparian mustelids in river valleys of NE Belarus. Acta Theriologica, 45: 233-242.

Sidorovich, V.E. 2001. Study on decline in the European mink *Mustela lutreola* population in connection with the American mink *M. vison* expansion in Belarus:

story of the study, review of the results and research priorities. Säugetierkundliche Informationen, 5: 133-153.

Sidorovich, V., Kruuk, H. y Macdonald, D.W. 1999. Body size and interactions between European and American mink (*Mustela lutreola* and *M. vison*) in Eastern Europe. Journal of Zoology, 248: 521-527.

Sidorovich, V.E. y Macdonald, D.W. 2001. Density dynamics and changes in habitat use by the European mink and other native mustelids in connection with the American mink expansion in Belarus. Netherlands Journal of Zoology, 51: 107-126.

Sidorovich, N.V., Macdonald, D.W., Kruuk, H. y Krasko, D.A. 2000. Behavioural interactions between the naturalized American mink *Mustela vison* and native riparian mustelids, NE Belarus, with implications for population changes. Small Carnivore Conservation, 22: 1-5.

Skirnisson, K. 1980. The mink in Iceland. “Villt Spendyr”, Rit Landverndar, 7: 80-94.

Smal, C.M. 1988. The American mink *Mustela vison* in Ireland. Mammalian Review, 18: 201-208.

Smal, C.M. 1991. Population studies of feral mink *Mustela vison* in Ireland. Journal of Zoology London, 224: 233-249.

Smith, R.H. 1994. Rodent control methods: non-chemical and non-lethal chemical. En: Buckle, A. P y Smith, R.H (eds.). Rodent pest and their control. CAB International. Wallingford, Oxon, UK. Pp: 109-125.

Stevens, R.T., Ashwood, T.L. y Sleeman, J.M. 1997. Fall-early winter home ranges, movements, and den use of male mink, *Mustela vison* in eastern Tennessee. Canadian Field Naturalist, 111: 312-314.

Stroganov, S.U. 1962. Carnivourous mammals of Liberia. Traduction Israel Program for Scientific Translations, Jerusalem.

Sundqvist, C., Amador, A.G., y Bartke, A. 1989. Reproduction and fertility in the mink (*Mustela vison*). Journal of Reproduction and Fertility, 85: 413-41.

Teerink, B.J. 1991. Hair of West-European mammals. Cambridge: Cambridge University Press.

Thom, M.D., Harrington, L.A. y Macdonald, D.W. 2004. Why are American mink sexually dimorphic? A role for niche separation. Oikos, 105: 525-535.

Thompson, H.V. 1962. Wild mink in Britain. New Scientist, 13: 130-132.

Tuyttens, F.A.M. y Macdonald, D.W. 1998a. Fertility control: an option for non-lethal control of wild carnivores? Animal Welfare, 7: 339-364.

Tuyttens, F.A.M. y Macdonald, D.W. 1998b. Sterilization as an alternative strategy to control wildlife diseases: bovine tuberculosis in European badgers as a case study. Biodiverisity and Conservation, 7: 705-723.

Tuyttens, F.A.M. y Macdonald, D.W. 2000. Consequences of social perturbation for wildlife management and conservation. En: M. Gosling & W. Sutherland (eds). Behaviour and Conservation. Cambridge, University Press, Cambridge, UK. Pp: 315-329.

Vidal-Figueroa, T. y Delibes, M. 1987. Primeros datos sobre el visón americano (*Mustela vison*) en el suroeste de Galicia y noroeste de Portugal. Ecología, 1: 145-152.

Wise, M.J., Linn, I.J. y Kenedy, C.R. 1981. A comparison of the feeding biology of mink *Mustela vison* and otter *Lutra lutra*. Journal of Zoologici Fennici, 166: 1-48.

Wittenberg, R. y Cock, M. J. W. 2001: Invasive Alien Species: A Toolkit for Best Prevention and Management Practices. CAB International, Wallingford, Oxon, UK.

Wozencraft, W.C. 1989. The phylogeny of the recent Carnivora. En: Gittleman, J.L. (ed.). Carnivore Behaviour, Ecology and Evolution. New York: Cornell University Press, USA. Pp: 495–453.

Ward, D.P., Smal,C.M. y Fairley, J.S. 1986. The food of mink *Mustela vison* in the Irish Mitlands. Proceedings of the Royal Irish Academy, 86B: 169-182.

Yamaguchi, N. y Macdonald, D.W. 2003. The burden co-occupancy: intraspecific resource competition and spacing patterns in American mink, *Mustela vison*. Journal of Mammalogy, 84 (4): 1341-1355.

Yamaguchi, N., Rushton, S. y Macdonald, D.W. 2003. Habitat preferences of feral American mink in the upper Thames. Journal of Mammalogy, 84 (4): 1356-1373.

Zabala, J., Zuberogoitia, I., Garin, I. y Aihartza, J.R. 2001. Small carnivore trappability: seasonal changes and mortality. A case study on European mink *Mustela lutreola* and spotted genet *Genetta genetta*. Small Carnivore Conservation, 25: 9-11.

Zielinski W. J., Spencer W. D. y Barret R. H. 1983. Relationship between food habits and activity pattern of pine marten. Journal of Mammalogy, 64: 387-396.

Anexos

Anexo I. Ficha de muestreo del visón americano.

CONTROL DE LA ESTACIÓN DE TRAMPEO
TRAPPING STATION CONTROL

Localidad/State:
Municipio/Town:
Altitud/Altitude:
U.T.M.:

Fecha colocación/Placing date:
Fecha retirada/Removing date:

Responsable/Person in charge:

Río/River:
Cuenca/Basin:

Longitud (m)/ Lenght:
Trampas noche/Traps per night:

	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
Total										

Anexo II. Ficha individual de identificación de los ejemplares capturados.

FICHA DE CAPTURA DE CARNÍVOROS
CARNIVORE TRAPPING CARD

Zona de trampeo/Trapping area:
Río/River:
Altitud/Altitude
Cuenca/Basin:
Nº y Tipo trampa/Nº and type of trap:
U.T.M.:
Fecha captura/Capture date:
Equipo/Team:

Especie capturada/Trapped species:

Mustela lutreola *Mustela putorius* *Mustela vison* *Mustela nivalis*
Mustela erminea *Martes foina* *Martes martes* *Genetta genetta*
Felis catus Indeterminado ___________ _____________

Sexo/Sex: M/M H/F **Edad/Age**: Cría /Pup Jóven/Juvenile SA/SA A/A

Medidas externas/External measures (mm; g):

Peso/Weight:
Longitud pie posterior (PP)/Hindfoot lenght:
Longitud cola (C)/Tail lenght:
Longitud pie anterior (PA)/Forefoot:
Longitud Total (LT)/Total length:
Longitud oreja (O)/Ear lenght:
Longitud cuerpo (sin cola) (CC)/Body length (without tail):

Manchas del pelaje/Fur spots

Zona del morro/Snout area	Vientre y dorso/Abdomen and back

Estado sexual/Sexual state:

Machos/Males: Inactivo/Inactive
Testículos extraabdominales/Extrabdominal testicles
Copula/Copulation

Hembras/Females: Inactiva/Inactive
En celo/In heat
Vagina copulada/Copulated vagina
Con pezones ( )/With nipples ( )
Preñada/Pregnant
Amamantando/Breast feeding
Criando/Breeding

Parásitos/Parasites:

Especie/Species	Tamaño/Size	Número/Number	Posición/Position

Anestesia suministrada/Anaesthesic:

Anestésico/Anaesthesic	Dosis (ml)	Tiempo dormir/ Time to get asleep (min)	Tiempo despertar/ Time to wake up (min)

Anotaciones especiales (heridas producidas, alguna marca especial, muestras recogidas, etc.):
Special notes (injuries, special marks, taken samples, etc.):