Table 2
Summary of birds, marine mammals, and finfish found to contain domoic acid via natural exposure. For a comprehensive list of shellfish species shown to contain domoic acid see Landsberg (2002) and Table 12-2 in Trainer et al. (2008).

Organism	Region	Reference study
Birds		
Brown pelican (*Pelicanus occidentalis*)	California, USA Cabo San Lucas, Mexico	Work et al. (1993), Sierra-Beltran et al. (1997)
Brandt's cormorant (*Phalacrocorax penicillatus*)	Central California	Work et al. (1993)
Marine mammals		
Blue whale (*Balaenoptera musculus*)	California, USA	Lefebvre et al. (2002a)
Humpback whale (*Megaptera novaengliae*)	California, USA	Lefebvre et al. (2002a)
Dwarf sperm whale (*Kogia sima*)	Southeastern & mid-Atlantic Coast, USA	Fire et al. (2009)
Pygmy sperm whale (*Kogia breviceps*)	Southeastern & mid-Atlantic Coast, USA	Fire et al. (2009)
Bottlenose dolphin (*Delphinus capensis*)	Sonora, Mexico	Sierra-Beltran et al. (2004)
Minke whale (*Balaenoptera acutorostrata*)		Cordaro and Berman (unpublished data from the NMFS National Marine Mammal Health and Stranding Program)
Common dolphin (*Delphinus*)	California, USA	Cordaro and Berman (unpublished data from the NMFS National Marine Mammal Health and Stranding Program)
Harbor porpoise (*Phocoena phocoena*)	California, USA	Gulland (unpublished data)
California sea lion (*Zalophus californianus*)	California, USA	Lefebvre et al. (1999), Scholin et al. (2000)
Northern fur seal (*Callorhinus ursinus*)	California, USA	Gulland and Lefebvre (unpublished data)
Sea otter (*Enhydra lutris*)	California, USA	Lefebvre (unpublished data)
Fish		
Albacore (*Thunnus alalunga*)	California, USA	Lefebvre et al. (2002a)
Anchovy (*Engraulis mordax*)	California, USA	Lefebvre et al. (2002b)
Chub mackerel (*Scomber japonicus*)	California, USA Cabo San Lucas, Mexico	Sierra-Beltran et al. (1997), Lefebvre et al. (2002a), Busse et al. (2006)
Curlfin turbot (*Pleuronectes decurrens*)	California, USA	Vigilant and Silver (2007)
Dover sole (*Microstomus pacificus*)	California, USA	Vigilant and Silver (2007)
English sole (*Pleuronectes vetulus*)	California, USA	Vigilant and Silver (2007)
European sardine (*Sardina pilchardus*)	Portugal	Vale and Sampayo (2001), Costa and Garrido (2004)
Jack mackerel (*Trachurus symmetricus*)	California, USA	Busse et al. (2006)
Jack smelt (*Atherinopsis californiensis*)	California, USA	Lefebvre et al. (2002a)
Lonespine combfish (*Zaniolepis latipinnis*)	California, USA	Busse et al. (2006)
Pacific halibut (*Hippoglossus stenolepis*)	California, USA	Vigilant and Silver (2007)
Pacific sanddab (*Citharichthys sordidus*)	California, USA	Lefebvre et al. (2002a), Busse et al. (2006), Vigilant and Silver (2007)
Pacific sardine (*Sardinops sagax*)	California, USA	Lefebvre et al. (2002b)
Petrale sole (*Eopsetta jordani*)	California, USA	Vigilant and Silver (2007)
Rex sole (*Errex zachirus*)	California, USA	Vigilant and Silver (2007)
Sand sole (*Psettichthys melanostictus*)	California, USA	Vigilant and Silver (2007)
Staghorn sculpin (*Leptocottus armatus*)	California, USA	Fire and Silver (2005)
Slender sole (*Eopsetta exillis*)	California, USA	Vigilant and Silver (2007)
White croaker (*Genyonemus lineatus*)	California, USA	Fire and Silver (2005)

potential human health risks, but there appear to be vast differences in DA tolerances with dietary exposure between vertebrate species (Table 3). These differences are important to consider when developing oral dose animal models for establishing human health protection standards.

Based on the available data from oral dose toxicity studies, humans appear to be more sensitive to DA and experience excitotoxic effects at doses several times lower than rodent mammalian model species and fish (Table 3). When used as an agent to kill intestinal parasites, DA doses of approximately 0.4–0.8 mg/kg body weight were given to Japanese children with no apparent adverse effects (Daigo, 1959a). During the Prince Edward Island ASP event, dietary doses of 0.2–0.3 mg/kg also appeared to have no observable effects, while 0.9–2.0 mg/kg doses resulted in mild GI problems and 1.9–4.2 mg/kg doses caused confusion, disorientation, and seizures (Table 3). In contrast, mice and rats can tolerate oral doses of 28–60 mg/kg without observable adverse effects (Iverson et al., 1989). There are no available estimates for oral dose exposures that are known to induce clinical signs of toxicity in marine mammals. However, the fact that DA poisoning has been a recurrent problem for California sea lion populations in Central California suggests that they are at least as sensitive to DA as humans and may be a good sentinel species for assessing DA-induced human health impacts (Gulland et al., 2002).

In addition to neurobehavioral impacts, DA toxicity has also been shown to induce histopathological effects in the vertebrate central nervous system (CNS) (Pulido, 2008). Most of the studies performed to characterize histopathology associated with DA excitotoxicity have utilized systemic exposures in traditional mammalian model species (Tryphonas et al., 1990a,b; Strain and Tasker, 1991; Friedberg and Ross, 1993; Scallet et al., 1993; Schmued et al., 1995; Wang et al., 2000; Cheng et al., 2002; Qiu and Curras-Collazo, 2006). However, natural dietary exposures associated with toxigenic *Pseadonitzschia* blooms have also confirmed the presence of DA-induced lesions in the CNS of